Vol. XV. — No. 8. August 1933.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

The simplification and cheapening of permanent way upkeep by using an elastic rail support,

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Elasticity is scientifically defined as the property of bodies to return spontaneously to their normal form, after the latter has been modified within certain limits by the application of an exterior force, as soon as this force ceases to act.

Under the influence of shocks produced by vehicles in motion, the track and its constituent parts, if not elastic or if not sufficiently elastic, inevitably undergo deformation, which subsequently *does not disappear* of itself; on the contrary it persists in the form of wear within the limits allowed or as defects in the cohesion and levelling off of the track.

With existing designs of permanent way, there is no method of rendering these main enemies of good track innocuous; *sufficient elasticity of the track as a whole is lacking.*

The destructive results of the shocks in question *must*, therefore, reveal themselves at the end of a more or less short period of time.

The elasticity of wood sleepers is low and the trough-shaped metal sleepers have none. The logical conclusion to be drawn from these facts is the following :

The track must be made sufficiently elastic; the result will be the suppression of the harmful effects of the shocks occurring in service. This object can be attained if these shocks are directly absorbed by a hollow sleeper acting as a spring. To ensure this, the hollow sleeper must be so intimately connected with the rail subjected to the shocks as to form a single piece, so that the effects of these shocks are only reflected transiently as a slight deformation, in the sides and bearing surfaces of the sleeper. Finally the pressures, reduced in this way, must be transmitted to a bed of stone ballast, well consolidated and levelled up.

When properly prepared, this stone ballast has the property of forming a support of constant flexibility for carrying the static load of the sleepers; the same could not be guaranteed in the case of loose stone ballast which gradually settles under tamping and shock.

In this way the whole of the effects of the harmful shocks on the track run over by the rolling loads can be definitely eliminated, which effects show themselves

more particularly in well known ways at the rail joints. Now, if the joints are no longer exposed to shocks, the play thereat can be suppressed. Up to the present, it has been considered that this play could not be done away with owing to the expansion of the rails. However, in the case of rails on hollow sleepers most of the heat flows to the sleepers and the ballast as a result of the rigid connection between the rail and the sleeper. The joint, up to the present time the weakest point of the railway track, becomes as strong as the rail, thanks to the rigid way the rail is fastened to the sleeper and to the rigid fishing, and this simplifies the maintenance of the track to a large extent.

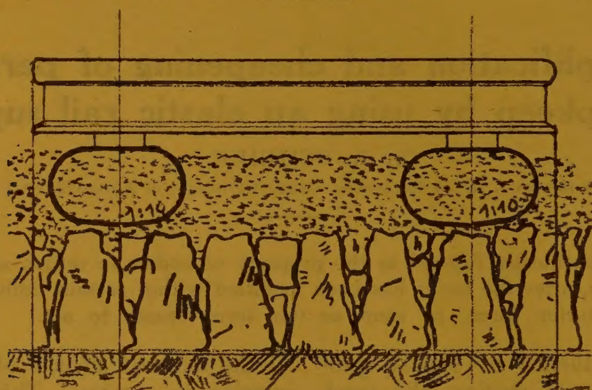


Fig. 1.

We give below a comparative statement of the maintenance work required for safe operation when using :

A) present type of permanent way;

B) permanent way using hollow metal sleepers.

This statement also shows the work rendered unnecessary when the rail is supported elastically by the hollow sleeper, and the great simplification in the upkeep of the permanent way resulting therefrom. This simplification means very important savings.

A.	B.
Present type of permanent way.	*Permanent way using hollow steel sleepers.*
1.	1.
The track has to be lifted owing to the sleepers being driven into the ballast by the shocks arising in service.	*Becomes unnecessary.* — The hollow sleeper rests directly on the levelled off rammed ballast. The pressure due to the shocks is converted by the elasticity of the sides of the sleeper into a statical supporting pressure which disappears when the rolling load has passed.

2.	2.
Correcting irregular spacing of sleepers. Use of anticreep devices.	*Becomes unnecessary.* — As a result of being rigidly fastened together the position of the rails and sleepers cannot change. The longitudinal forces to which the rails are subjected are absorbed by a momentary elastic deformation from the trailing side to the front side of the cross section of the sleeper.
3.	3.
Adjustment of the play at the joints. Replacing rails that have crept.	*Becomes unnecessary through* laying rails without play. The greater part of the expansion of the rails is removed by the heat being diverted towards the ballast and the hollow sleeper, the latter undergoing a slight change of its side curvature (cf. paragraph 11).
4.	4.
Tightening up the rail fastenings and fish plates.	*Becomes useless* through the rigid connection of the rails to one another and to the hollow sleeper. The pressure on the rail of a well tightened up bolt may be as much as 8 000 kgr. (17 600 lb.) and transfers the effects of the shocks from the point of fixation to the bearing of the sleeper. The bearing surface of the nuts is therefore not distorted and self slackening back of the nuts becomes impossible.
5.	5.
Elimination of the effects of frost on the permanent way.	*Becomes unnecessary.* — Any alteration in the alignment of the rails in the vertical direction caused by the effects of frost is taken up by the elasticity of the cross section of the sleeper. As a result, the number of broken rails is reduced to a considerable extent.

6. Repairing the rail bearings, necessitated by the bearing plates being driven into the wood of the sleeper or, in the case of metal sleepers, by excessive wear of the bearing surface. Renewal of worn sleepers.	6. *Becomes unnecessary.* — The rigid fastening of the rail on the hollow sleeper reduces the two parts into one single unit; because of this fact, they *automatically become inseparable.* Any movement and any wear by rubbing at the point of fastening are impossible. During the passage of the rolling load, the surface of the hollow sleeper follows the line of the elastic flexion of the rail.
7. Elimination of the irregularities produced in service in the transverse level of the track.	7. The form of the hollow sleeper also lends itself to yielding, to some extent, to the lateral pressure produced by the shocks. *In addition, the hollow sleeper is protected against transverse movement by the cover plates* placed before the openings in it. Warping of the track is therefore impossible.
8. Renewal of small parts after unexpectedly heavy wear, and of rails with battered ends, as well as the elimination of high and low places in the track.	8. Not needed as the rigid fastening of rail to hollow sleeper resists all movement at the point of fastening and consequently prevents any great wear of the fastenings. The ends of the rails can neither lift nor drop while the wheels pass over the joint. The elastic deformation of the hollow sleeper guarantees the progressive transmission of the pressure exercised by the rolling load so that the destruction of the packing and the formation of cavities under the joints are not to be feared.
9. Correction of the gauge in sections of line out of gauge.	9. Cannot become necessary owing to the rigid fastening of the rails.

10.

Periodical relaying is essential as in spite of the intermediate maintenance work carried out, as mentioned under 1 to 9, there still exist defects such as, for example, the partial destruction of the packing material by the pick and by the shocks, making the structure of the ballast irregular and taking away from it the little elasticity it may retain.

10.

Becomes unnecessary because, through the elastic strength of the hollow sleeper and the layer of ballast, the ballast cannot be destroyed, and the properties of the hollow sleepers put an end to other work in between times. After the hollow sleeper has once been laid in the track repacking at intervals can be suppressed.

11.

The solution of the joint problem by the use of very long rails is not a perfect one. Serious disadvantages subsist (part of the play at the joints), and new ones are introduced (difficulty in handling abnormally long rails, etc.).

11.

The permanent way with hollow metal sleepers, with rails of normal length without play at the joints to interrupt the surface, perfectly meets the conditions of a continuous running surface, its internal construction making the effects of expansion due to temperature changes harmless (cf. section 3).

In addition to the work rendered unnecessary, as shown under B, the permanent way with hollow sleepers also *reduces to an appreciable extent the wear of all the component parts of the permanent way, even including the ballast.* Comparative tests of metal sleepers of the trough and hollow types were carried out in 1921-1922 at the Dresden Higher Technical School (*Organ für die Fortschritte des Eisenbahnwesens* 1923, page 142). In the first part of these tests, after 67 000 blows of 35 Kg.-M. (235 foot-pounds) from a falling tup, falling at an angle on the head of the rail, the fastening of this latter to the hollow sleeper showed 66 to 70 % less damage than in the case of the trough-shaped sleeper. The reduction of wear of the rails, sleepers and of the ballast is probably in the same proportions.

The exceptionally great savings due to result from the simplification of track maintenance work, as explained above, will be proved in practice.

The trial in 1923 of hollow metal sleepers in service near Dresden was the first demonstration of the properties of a rail support of this kind. The result was to replace the slope of 1 in 4 of the bearing surfaces of the sleepers by that of 1 in 10. It also showed that it was only by direct transmission through the rigid fastening of the rail of the shocks converted to a certain degree into static pressure by means of the spring action of the sleeper to the flexible layer of ballast, that the objective of the elastic support of the rails could be attained. This first demonstration cannot, therefore, be described as having shown that the new idea was a practical failure as has been said.

[621.132.6 (.44)]

New suburban locomotives for the French Nord Railway,

by Mr. DE CASO,

Engineer, Chief of the Locomotive Designing Office of the Nord Railway.

(*Revue Générale des chemins de fer.*)

As the use of steam locomotives has to be continued on the suburban lines of the French Nord Railway, a locomotive easily able to meet the increasing traffic demands on these lines had to be provided. This article describes the new locomotive which, fitted with the latest improvements, is the prototype of large numbers now being built. The locomotive in question is a 2-4-2 simple expansion, high superheat tank engine, with a large adhesive weight able, if need be, to work satisfactorily a heavy express train between Creil and Paris.

The locomotive to be described is the first of the 4.1200 series built by the Nord for its suburban locomotive stock; four engines of the same design are under construction in the Company's workshops; at the present time a further thirty are being built by private firms.

The construction of this type of engine has been subordinated to the principles considered the best at present in use as regards pressure.

a) *High superheat.* — The superheat temperature in normal working has been raised to about 380° C. (716° F.); it reaches 420° C. (788° F.) without difficulty when an effort is required from the locomotive on heavy up gradients.

b) *Simple expansion.* — Steam superheated in this way can be expanded to the greatest desirable extent in a simple expansion engine, thanks to the use of entirely independent admission and exhaust valves.

The valve gear used is the « Cossart » (1).

c) *Circulation of the steam.* — The passages have been arranged to conform as closely as possible to the laws governing the quickest movement of the steam.

The cylinders and passages were first of all designed and the details of the valves were then designed so that the steam could work under the best conditions.

d) *Valve motion.* — The cam shafts are driven by a simple articulated system of levers which in addition partially balances the inertia forces of the reciprocating parts.

e) The fact of being able to increase the load on the coupled wheels to 22 t. (21.65 Engl. tons) enabled us to build a locomotive with a high adhesive weight, with a boiler easily able to meet the demands of the improved suburban service.

The small diameter of the coupled wheels (1.55 m. = 5 ft. 1 in.), the large adhesive weight and the high speed of rotation of the motor as well as the excellent behaviour of the engine when running enables us to combine the respective advantages of express and goods engines.

Experience has shown that, as we expected, these suburban locomotives will be able to haul with ease the heavy rakes of all-metal stock (loaded weight 500 t. = 492 Engl. tons) that will be used in the future, in shorter times than those allowed with the present trains of wood stock (weight 330 t. = 324.7 Engl. tons), and when necessary to haul in a highly satisfactory manner express

(1) Cf. *Revue Génerale des chemins de fer*, February 1933, page 178.

trains between Creil and Paris, should assistance be required at any intermediate point.

f) The following table gives the *leading characteristics and dimensions :*

Boiler pressure			18 Hpz. (261.2 lb. per sq. inch).
Grate		Length	3.10 m. (10 ft. 2 in.).
		Width	1.00 m. (3 ft. 3/8 in.).
Smoke tubes	Superheater tubes	Number	32
		Diameter	135/143 mm. (5 5/16 in. — 5 5/8 in.).
	Serve tubes	Number	65
		Diameter	65/70 mm. (2 9/16 in. — 2 3/4 in.).
	Smooth tubes	Number	36
		Diameter	45/50 mm. (1 49/64 in. — 1 31/32 in.).
Distance between tube plates			4.750 m. (15 ft. 7 in.).
Cylinders		Diameter	640 mm. (25 1/4 in.).
		Stroke	700 mm. (31 11/16 in.).
Diameter of wheels		Coupled	1.550 m. (5 ft. 1 in.).
		Truck	950 mm. (3 ft. 1 3/8 in.).
Weight of the locomotive		Empty	98 t. (96.45 Engl. tons).
		In working order	122 t. (120.10 Engl. tons).
Water			10 m³ (2 200 Br. gallons).
Coal			5 t. (4.9 Engl. tons).

A. — *Boiler.* — The construction of the boiler and fittings was subordinated to our first programme of standardisation as recently described in the *Revue Générale* [1] (it is based on the standardisation of the *Pacifics* 31.200).

The same superheater is used.

The ashpan and its mobile parts are carried by the boiler alone, and a blowdown cock operated by the fireman from the cab is also fitted.

B. — *Two-cylinder simple expansion engine.* — Separate admission and exhaust valves are used. Poppet valves and piston valves were tested out on the same engine and the latter showed themselves distinctly the better for the important reason that they are moving at the moment of uncovering and covering the ports. The wire-drawing is also reduced and the way the engine gains speed is quite remarkable (fig. 2).

The piston valves have shown themselves to be tighter than the poppet valves.

(1) February 1933 issue, p. 178.

The following additional advantages may be added to the above fundamental ones :

1. The valve gear is almost completely outside the action of the steam;

2. Easy maintenance.

Figure 2 clearly shows the method of construction; the liner with its ports in which the piston valve works is made from nitralloy steel. Cast iron was not suitable owing to the high stresses to which the bridges are subjected by the pressure of the steam acting on the bottom of the liner.

The valves are arranged vertically so that the cylinders can be filled as quickly as possible. We wished to avoid the drawbacks inherent to piston valves, certain areas of which are less effective. In addition the vertical centre line is in the axial plane of the ports.

An arrangement of this kind with the best profile of the walls in contact with the steam is the one which ensures at once the quickest filling of the cylinders, the reduction of the zones of eddy

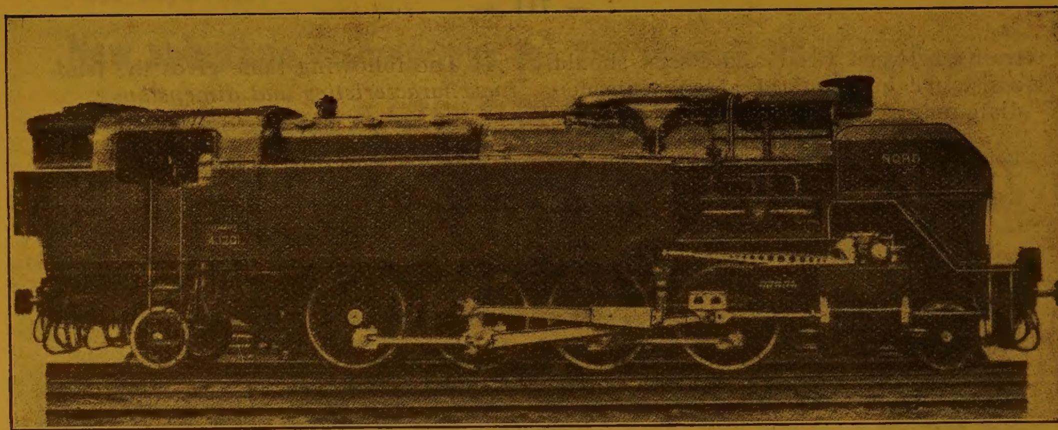


Fig. 1.

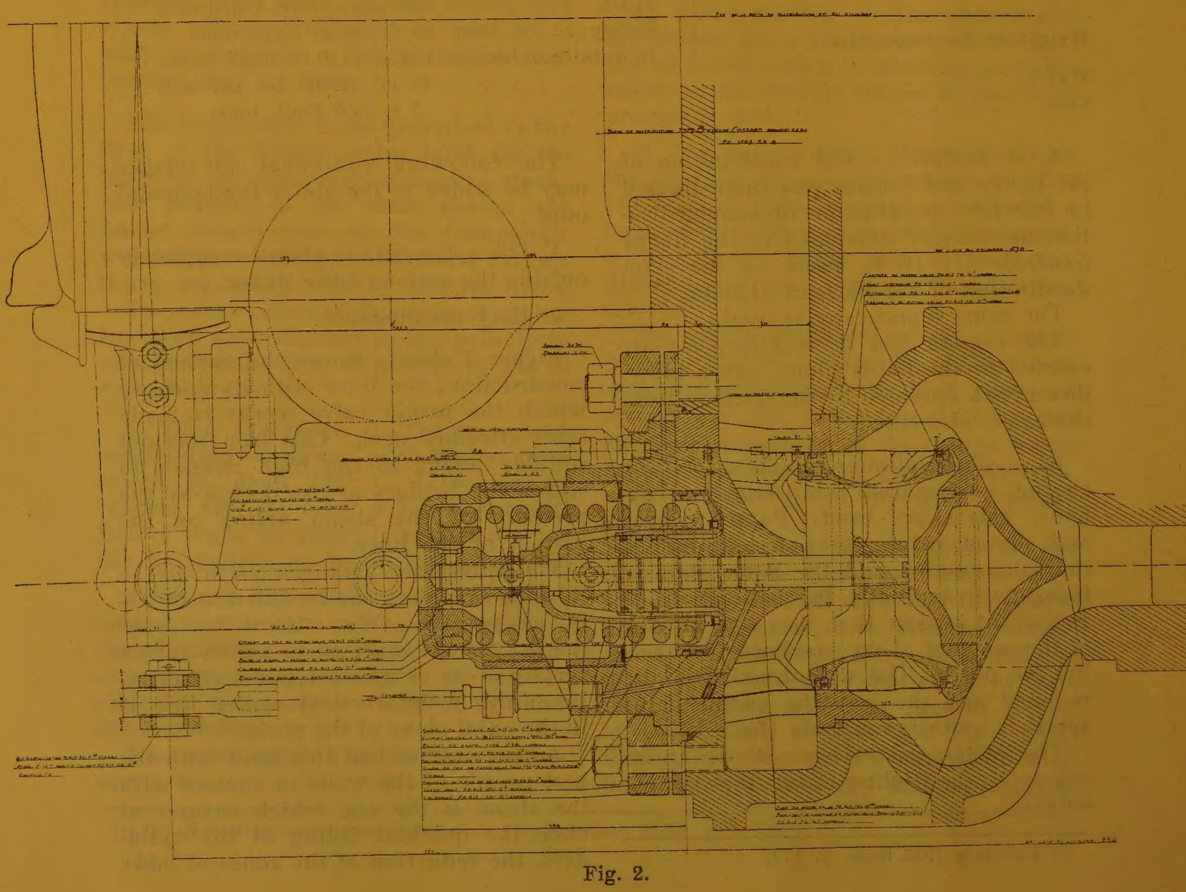


Fig. 2.

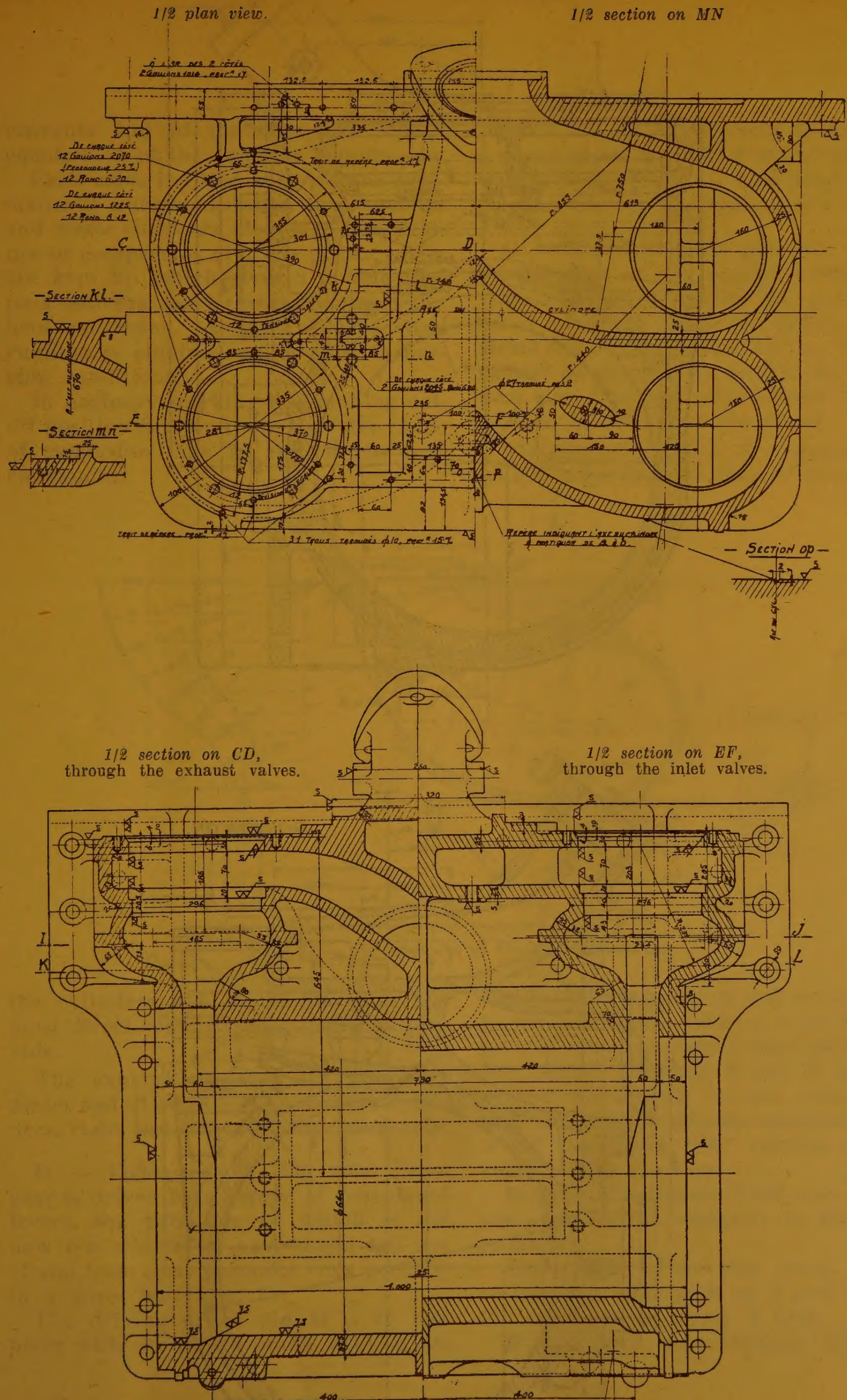
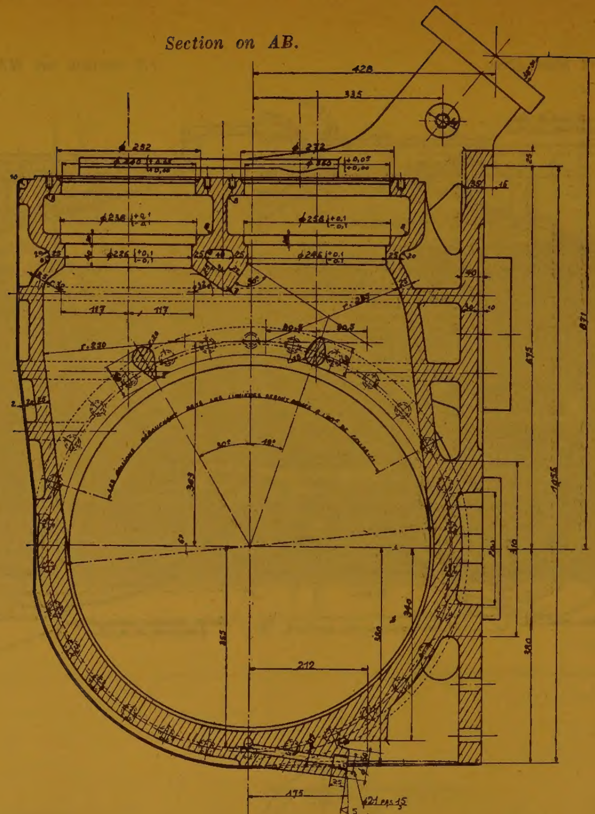

1/2 plan view.
1/2 section on MN
1/2 section on CD, through the exhaust valves.
1/2 section on EF, through the inlet valves.

Fig. 3.

Section on AB.



Section on GH.

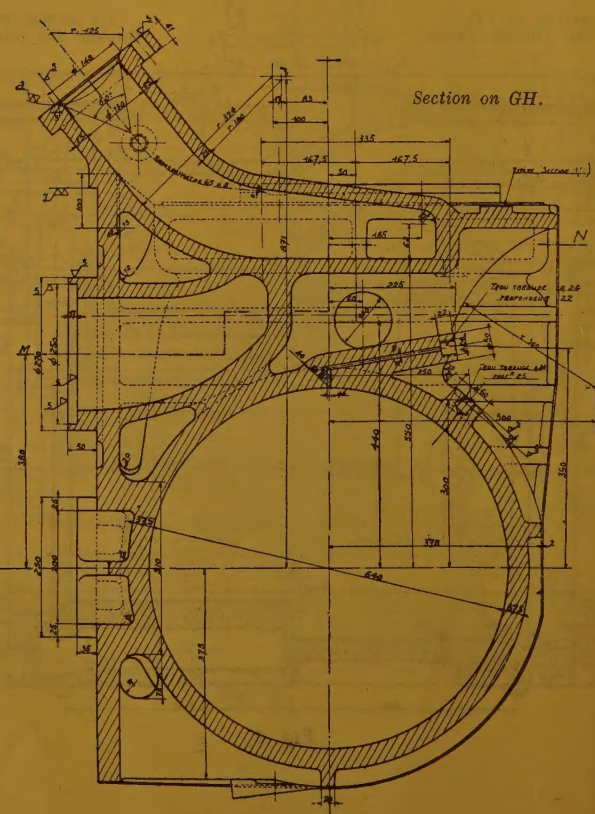


Fig. 4.

currents and of the clearance which equals 8 % of the cylinder volume.

Each valve is fitted with pistons automatically subjected, when the regulator and waste cocks are closed, to the pressure of compressed air : the piston valves are kept up which gives a double byepass and the cams revolve without any load on them. A sort of free-wheel running is obtained under very favourable conditions.

In ordinary working the running cut-off position is 7 % giving a greater range of expansion than in any of our best compounds.

10 % cut-off is sufficient to maintain a speed of 112 km. (69.6 miles) an hour with a train of 482 t. (475 Engl. tons) on a continuous up gradient of 1 in 200.

C. — *Cylinders and passages.* — An examination of the cylinder drawings (figs 3, 4 and 5) shows the great care taken to ensure a free circulation of the steam. The admission valves are arranged on the outside so that the cylinders may expand freely without damage to their fastenings to the frame.

The pistons are also of a special form which helps the free flow of steam into

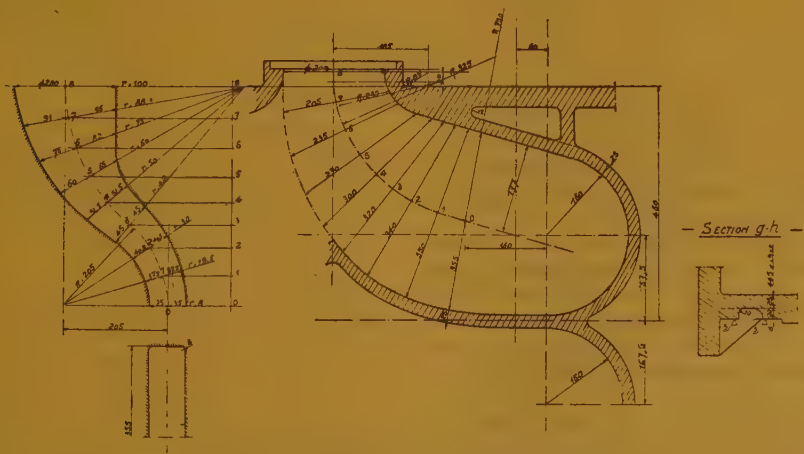


Fig. 5. — Development of the exhaust passage.

the cylinders, the steam following the most direct route it was possible to provide.

The exhaust passages are also very direct and of large section and the cylinders, right and left, are interchangeable.

D. — *Valve gear.* — The rotary cam gear is driven by a system of articulated levers, the principle of which is not new but which we have made full use of and from some points of view perhaps in a novel way (fig. 6).

The driving crank pin M is in one piece with the return crank MOA so designed that the points M and A are at 180° to one another. A rocking lever BIB' oscillates about a pivot I supported from the frame. The ends B and B' are connected respectively to the ends A of the return crank already mentioned and A' of the crank O'M' carried on the shaft driving the cams.

In plan, the figures OABI and O'A'B'I are symmetrical relatively to the fixed point I.

The result is that the point A' describes the same path as A and follows the same law in terms of time.

If two such arrangements are con-

jugated on each of the right and left cranks, the movement of the shaft driving the cams will be *synchronous* with that of the driving axle.

As the points B and B' are moreover in opposite phase with the reciprocating parts, a sufficiently heavy mass fastened to the rod MB near B will balance, to

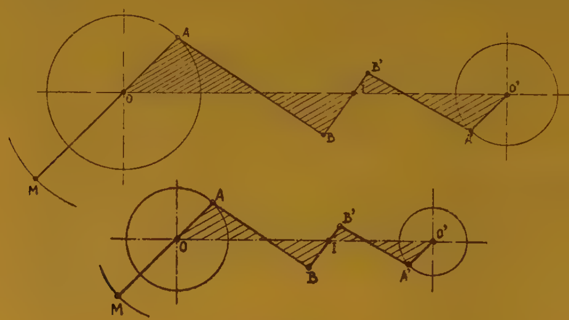


Fig. 6.

the proportions decided upon, the inertia forces due to the piston, crosshead, etc., on the same side and without any mechanical complication or maintenance cost. (The weight of the mass has been made 500 kgr. = 1 100 lb.).

Care must be given to the different movements of the driving axle in its guides. The rods like B'A' are fitted with a spring under an initial load of 500 kgr. (1 100 lb.) which protects the mechanism and the cam box at the same time.

This arrangement behaves perfectly at speeds of 7 revolutions per second without any trace of fatigue.

The joints are of the ordinary circular ended type lubricated with thick grease.

The running of the locomotive both under steam and coasting is remarkably good.

The above diagram shows the very appreciable reduction of the hunting couple through the use of reciprocating balancing masses as well as the greater uniformity of the tractive effort (fig. 7). The plain line represents the result when the compensating mass was removed.

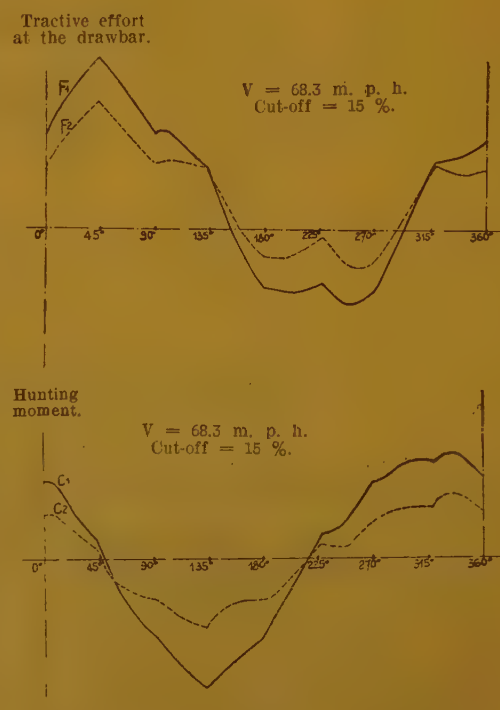
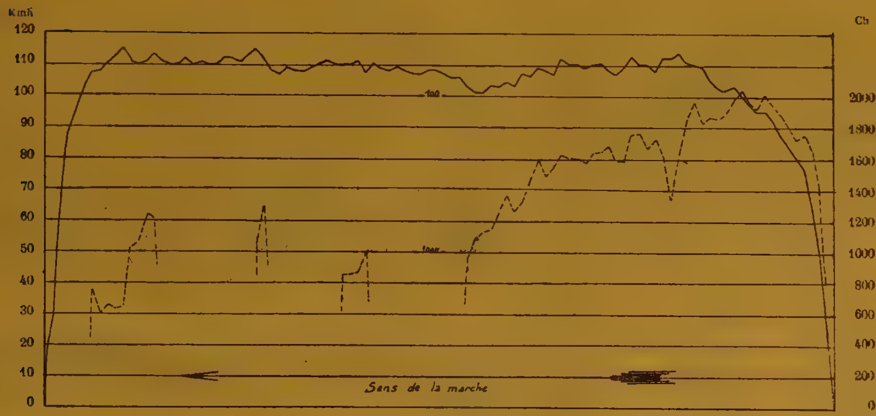


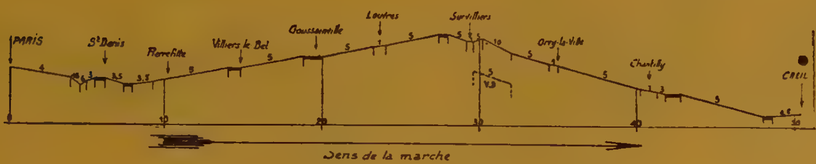
Fig. 7.

Principal details of the design.

Frame (See plate fig. 8). — Plates 25 mm. (63/64 inch) thick strongly cross braced, the axle box horns for each pair of axles being in one piece in cast steel so forming a strengthening plate to the frame.

Train S. D. 2 on the 26.7.32. — Load hauled : 475 Engl. tons.





Train S. D. 2 on the 8.8.32. — Load hauled : 475 Engl. tons.

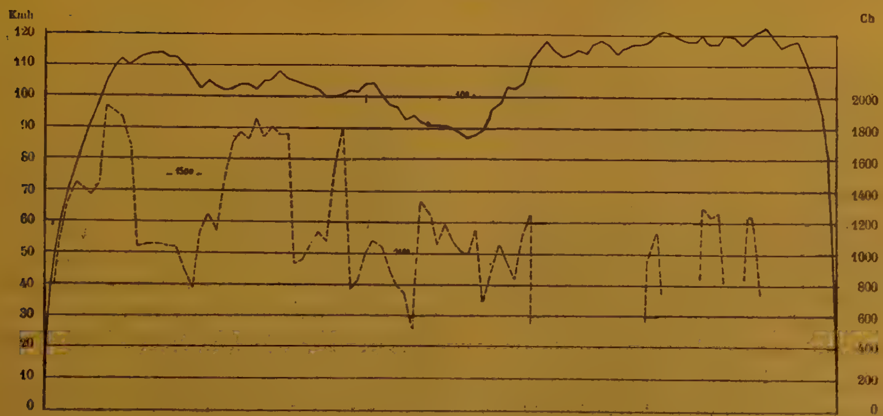


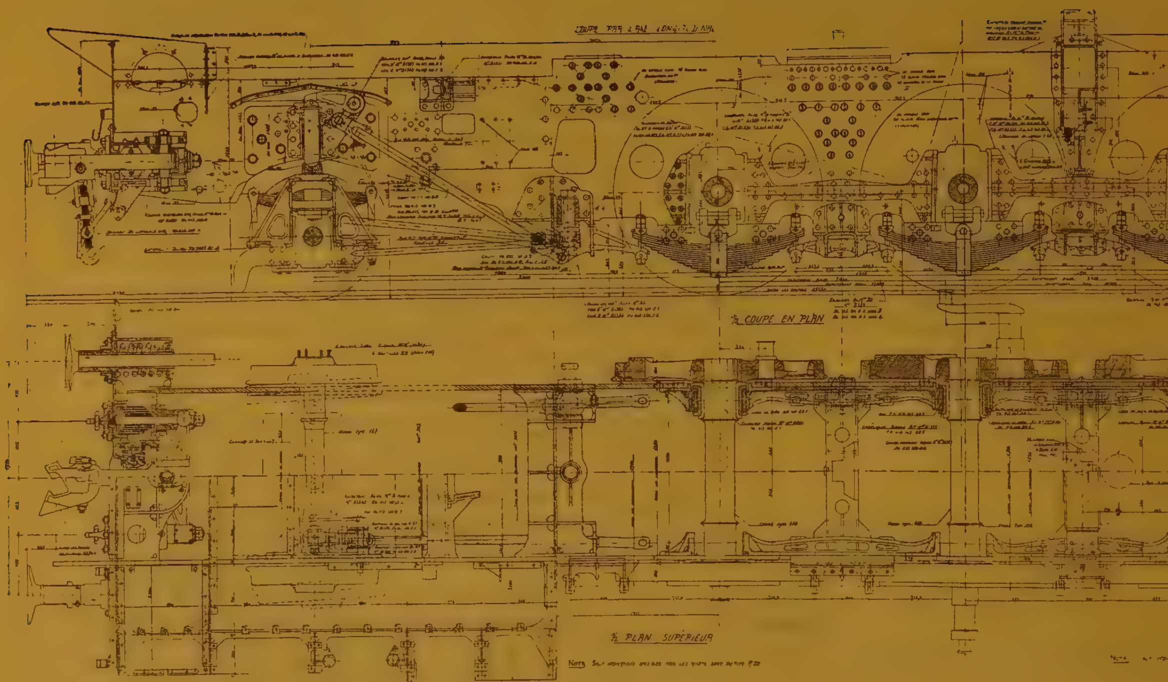
Fig. 8.

Note. — Kmh. = Kilometres per hour. — Ch. = H. P. — Sens de la marche = Direction of running.

One of the main cross stays braces the frame plates together, cross braces the water tanks to one another and forms the connection of the boiler to the frame.

The suspension is three point, the coupled axles and the trailing truck are compensated by means of equalisers.

The details of the draw and buffing gear designed for reversible running



combine the Willison automatic coupler and the standard gear as fitted to the all-metal suburban stock.

Mechanism. — The connecting and coupling rods are made of nickel chrome steel, lightened to the maximum extent possible. The connecting rod for example is 3.20 m. (10 ft. 6in.) long, carries a load of 50 t. (49.2 Engl. tons) and weighs only 200 kgr. (440 lb.).

The reciprocating balancing weight balances 40 % of the horizontal inertia forces, the balance weights in the wheels only dealing with the masses considered as being rotary.

The coupled wheels are fitted with the standard goods engine tyres [1.55 m. (5 ft. 1 in.) diameter].

The wheels and axles of the pony trucks are the same as those of the *Pacific* bogies.

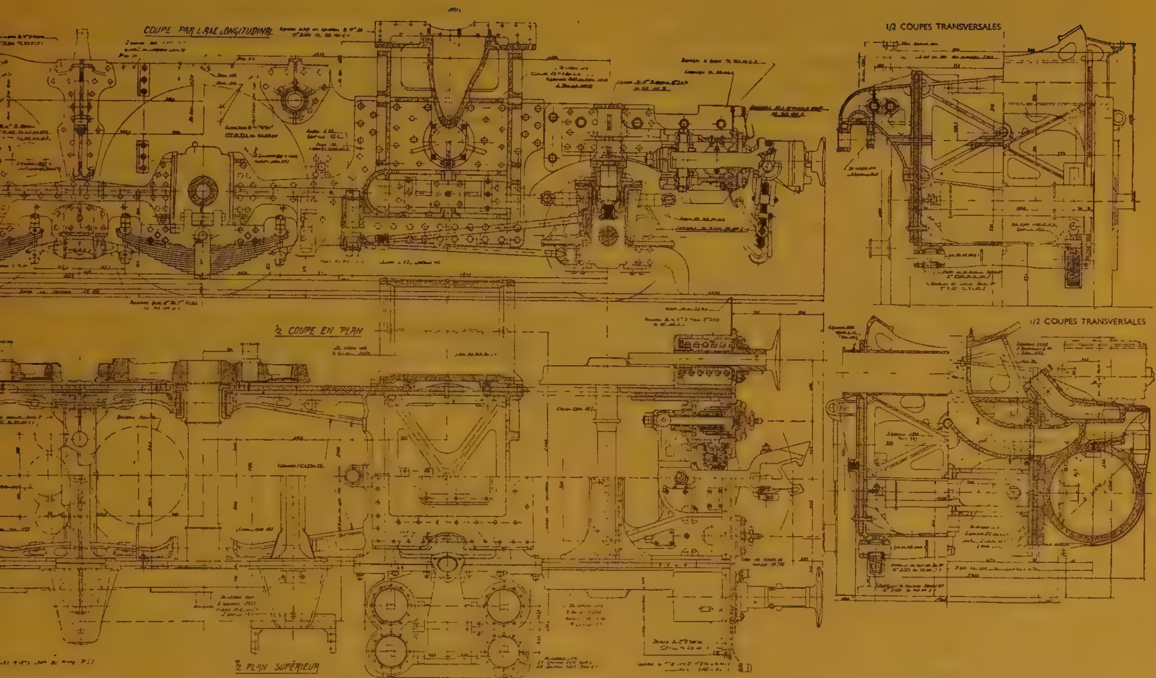
Plating. — The cab and bunker are welded up into one dust-tight unit. Part of the roof, however, is secured by bolts so that the boiler can be removed without taking down the cab, which is secured to the frame and when necessary will be repaired by welding.

Great attention has been given to the comfort of the enginemen.

The boiler back plate is heat insulated and a powerful electric fan carried above the lagging plate is available for the use of the men.

The long firing irons are made easier to handle by providing a tubular shaped holder which extends into the coal bunker.

A trolley running on rails holding



g. 9.

50 kgr. (110 lb.) of briquettes can be run up towards the firehole door to assist the fireman.

The coal hopper is so shaped as to give a good view when running in back gear with the least trouble from coal dust.

The gauges are grouped in an illuminated instrument board, and the left hand water tank has a level indicator with a float visible day and night.

The cab is fitted with one set of control gear but provision is made to fit a second set if the need should arise.

For reverse running the locomotive is fitted with the Aubert system distant control which, as is known, operates the regulator and the reverse gear from the driver's compartment in the last vehicle, a telephone with loud speaker completing the means of communications beween the driver and fireman.

A turbo-electric set of 3.5 kw. capacity supplies current required on the locomotive and for lighting the rake of stock.

It should be moreover pointed out that this locomotive, like all modern Nord locomotives, is fitted with electric lighting of the motion.

Lubrication. — The lubrication is as follows : two of our standard type 10-feed sectioned lubricators with Bourdon telescopumps arranged symmetrically, lubricate under pressure the driving axle boxes and guides, the cylinders and piston valves, suitable oil being supplied to each part.

The inlet piston valve spindles, and the steam chests are supplied with super-

heater cylinder oil moistened by means of saturated steam before injection.

The Tecalemit system of greasing is used to a large extent and in particular on the rubbing parts of the trucks and certain joints of the motions.

Running in.
Results of the first tests.

The first tests were carried out in order to ascertain the best material required, and the best design of the details of the valve box itself and the valves. In view of the high rates of acceleration to which these parts are subjected (108 m./sec./sec. at 100 km. = 354 feet/sec./sec. at 62 miles an hour), no error or half measure would stand up in practice.

At the present time all the problems arising have been solved, and in particular the poppet valves yield place to the piston valve, which in spite of the difficulties encountered has now been perfected.

This system has been developed in three months tests only. Many alterations were made to the arrangement existing on engine No. 4.1201, the others can only be made to engines 4. 1202 and following. The drawings given refer to this latter engine and those following it.

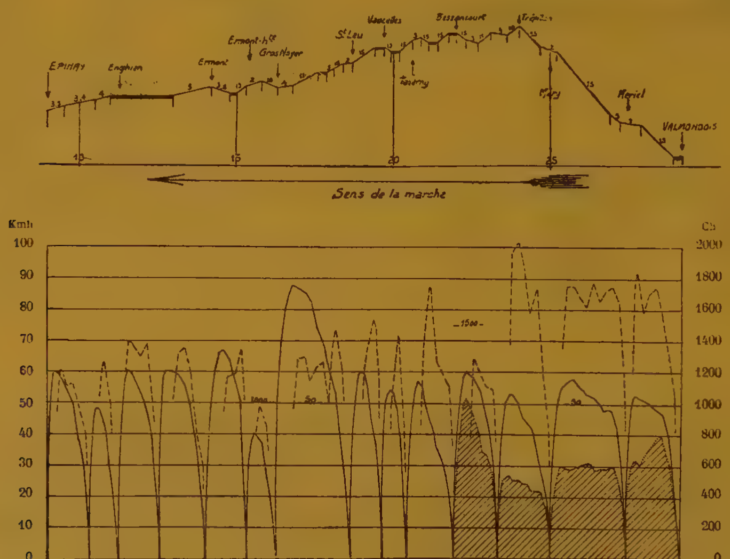


Fig. 10. — Train S. D. 4 on the 25-7-32. — Load hauled 475 Engl. tons.

Note. — The dotted line relates to the present trains of wooden stock.

Some results of tests.

The first tests locomotive 4. 1201 underwent were very severe. They were carried out with a train of 482 t. (475 Engl. tons) consisting of 9 loaded metal coaches and a dynamometer car.

The results largely confirmed our hopes.

The very instructive graphs on figures 8 and 10 relate to :

1. The Creil-Paris trip : time allowed. 32 minutes.

2. The Paris-Creil trip : time allowed, 30 min. 14 sec. (record for this run).

3. Very difficult Valmondois to Epinay section on stopping trains.

In the case of the latter, the speed of the present trains is shown by dotted lines.

The minimum time allowed to the fastest train from Creil to Paris not stopping at Creil is 32 minutes.

The figures of coal and water consumption will be given later on after consumption trials have been made.

These curves show clearly the abilities of this locomotive, which is able to develop and maintain over 1 700 H.-P. at the drawbar, the speed on a gradient of 1 in 200 being maintained at over 110 km. (68.3 miles) an hour without difficulty.

The engine behaves so well on the road and runs so freely with the regulator shut that the trial train maintained a speed of 95 km. (59 miles) an hour on a down gradient of 1 in 200 over more than 10 km. (6.2 miles).

The Nord Railway undoubtedly now possesses the locomotive needed to enable it to reorganise on modern bases and for steam traction alone, its important suburban service, so as to improve the passenger service from the three aspects of safety, comfort and speed.

[621.132.5 (.44)]

2-10-2 goods locomotives of the Paris-Lyons and Mediterranean Railway,

by E. SPIESS,

Ingénieur des Arts et Manufactures.

(Les Chemins de fer et les Tramways.)

Modern goods trains on main lines are like all other goods trains as regards the continual increase of load and commercial speeds. On some railways and in particular on certain sections of the Paris-Lyons & Mediterranean Railway (P.-L.-M.), extremely powerful locomotives have to be provided; in many cases 2 locomotives have to be coupled together in order to get the necessary adhesion and power needed, the former to make certain of having the necessary tractive effort and the latter to realise sufficiently high average speeds. Unfortunately with steam traction double heading results in operating complications which frequently upset the proper freedom of working of the service. It is consequently more profitable in such cases to use a single engine having the great tractive effort and high power needed.

Mr. Vallantin, the Chief Mechanical Engineer of the P.-L.-M. Railway, had this aspect of the question in mind when designing and building the new 2-10-2 locomotive. This engine is intended for working the Montargis-Nevers section on which the traffic requirements, the type of train hauled and the moderate axle loads allowed involved the use of at least five pairs of coupled wheels in order to have a pull of about 30 tons when starting and at low speeds, with a sustained power of up to 2 800 H. P. These requirements could easily have been met and even exceeded with an articulated engine with 6 or 8 pairs of coupled wheels, which would have passed round curves easily, with a very moderate axle load, with a tractive effort of over 30 tons at starting and with, at the same time, low fuel consumption (1).

The present practice and theory on the Paris-Lyons & Mediterranean led to another method of solving the problem, and the solution adopted has, it must be admitted, the merit of originality, boldness of concept, and good engineering practice. As it was decided to retain by all means compounding and to have a rigid locomotive with a long wheel base, it was decided to build a 2-10-2 engine with 4 outside cylinders, compound and fitted with poppet valves. The first two pairs of coupled wheels are driven by the low-pressure cylinders and the three other coupled pairs by the high-pressure.

The second and third pairs are coup-

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(1) At this point it should be pointed out that the Beyer-Garratt articulated locomotive is able to run at the same maximum speeds as the rigid type, this having been shown by the double *Pacific* passenger engine recently delivered to the P.-L.-M. (Algerian lines) which on the Laroche-Dijon line reached a maximum speed of 120 km. (75 miles) an hour without difficulty.

led by inside coupling rods and the high pressure cylinders are also carried on the frames, though on the outside, between these same pairs of wheels. This arrangement of four outside cylinders is particularly favourable from a maintenance point of view.

The leading dimensions of this engine, the major part of which was built by Messrs. Schneider & Co., are as follows:

4-cylinder compound 2-10-2 locomotive :

Overall length	16.250 m. (53 ft. 3 25/32 in.).	
Overall width	3.010 m. (9 ft. 10 1/2 in.).	
Height over chimney.	4.280 m. (14 ft. 1/2 in.).	
Total wheel base	12.800 m. (42 ft.).	
Rigid wheel base	7.200 m. (23 ft. 7 15/32 in.).	
Firebox :		
Inside length at foundation ring	2.467 m. (8 ft. 1 1/8 in.).	
Inside width at foundation ring	2.000 m. (6 ft. 6 3/4 in.).	
Grate area	5 m² (53.8 sq. feet).	
Boiler :		
Pressure	20 Hpz. (285 lb. per sq. inch).	
Outside diameter, first course	1.815 m. (5 ft. 11 15/32 in.).	
Height of boiler centre line	2.900 m. (9 ft. 6 13/64 in.).	
Distance between tube plates.	5.987 m. (19 ft. 7 45/64 in.).	
33 flue tubes, diameter	135 mm. (5 5/16 inches).	
141 smoke tubes, diameter	51 mm. (2 inches).	
33 superheater elements, diameter	28 mm.(1 1/8 inches).	
Heating surface :		
Firebox	23.24 m² (250.0 sq. ft.).	
Tubes	220.53 m² (2 373.8 sq. ft.).	
Total. . .	243.77 m² (2 623.8 sq. ft.).	
Superheating surface.	91.64 m² (986.4 sq. ft.).	
Total combined heating surface	335.41 m² (3 610.2 sq. ft.).	
Dabeg feed water heater.		
Cylinders :	2 H. P.	2 L. P.
Diameter	480 mm. (18 7/8 in.).	745 mm. (29 5/16 in.).
Stroke	650 mm. (25 5/8 in.).	700 mm. (27 1/2 in.).
Dabeg type « R. C. » poppet valve gear.		
Diameters of the wheels :		
Coupled	1.500 m. (4 ft. 11 in.).	
Leading pony truck	0.850 m. (2 ft. 9 1/2 in.).	
Trailing pony truck	1.260 m. (4 ft. 1 19/32 in.).	
Weight in working order :		
Adhesive	92.5 t. (91.0 Engl. tons).	
Total	122.4 t. (120.5 Engl. tons).	
Tractive effort at starting (compound) . . .	29.9 t. (29.4 Engl. tons).	
Maximum sustained horse power	2 820 H. P.	
Tender P.-L.-M. type.	(two 4-wheeled bogies).	
Water	28 t. (27.5 Engl. tons).	
Coal	7 t. (6.9 Engl. tons).	
Weight in working order	62.5 t. (61.5 Engl. tons).	
Total weight of engine and tender.	184.9 t. (182.0 Engl. tons).	

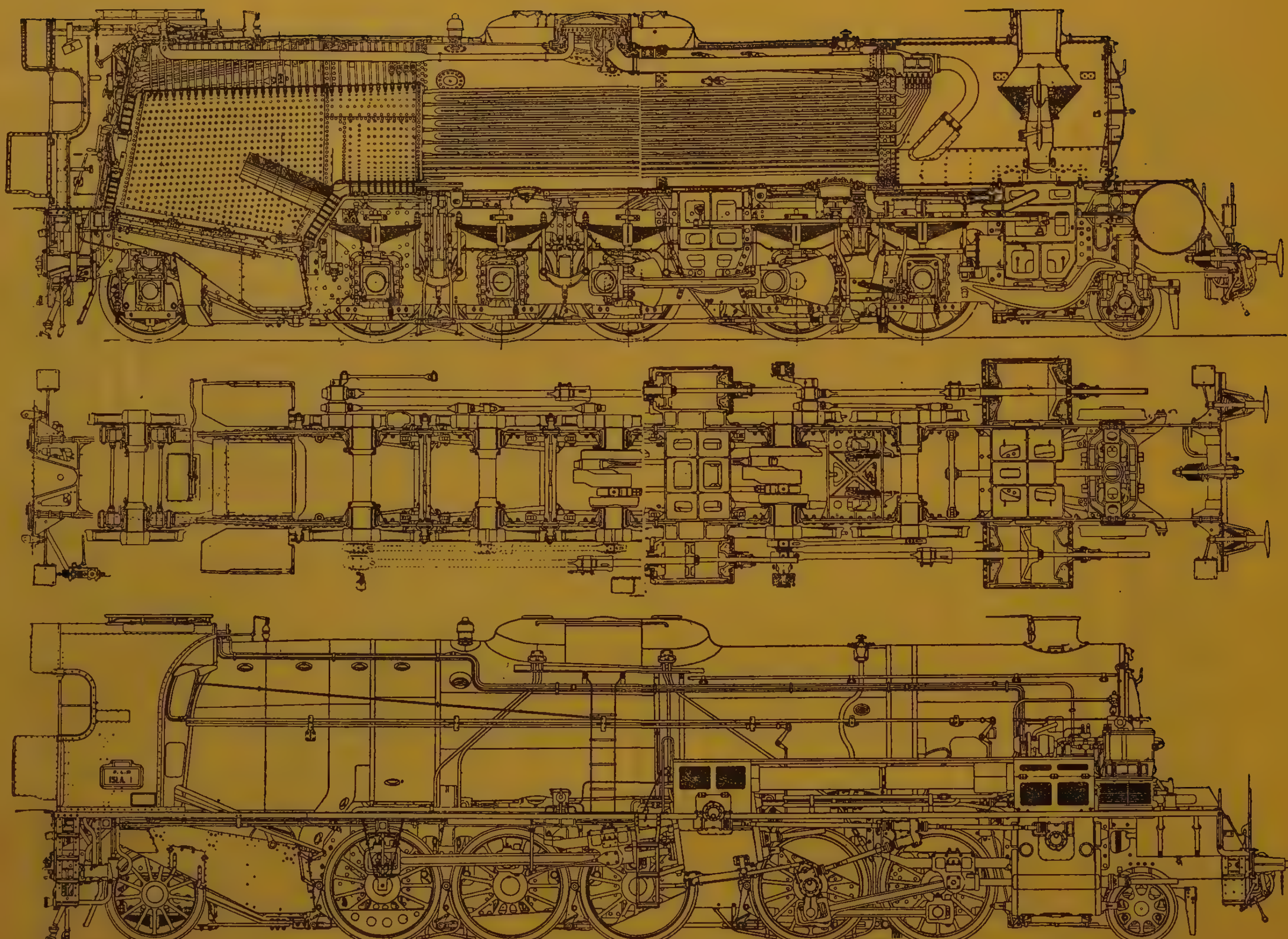

Fig. 1. — Section, plan and elevation of the 2-10-2 locomotive of the Paris-Lyons & Mediterranean Railway.

This powerful engine with its large coupled wheel base can pass round curves of 140 m. (7 chains) radius as required by the Paris-Lyons & Mediterranean gauge. The maximum load on the coupled axles is the moderate one of 18. 5 t. (18.2 Engl. tons).

The most original part of this locomotive lies in the driving gear : the rest of it conforms with other modern powerful engines of the Company.

* * *

1. Boiler.

The boiler closely resembles those of the *Mountain* and *Pacific* engines with 20-Hpz. (285 lb. per sq. inch) pressure, and it has a high coefficient of evaporation and great capacity. With a water level of 85 mm. (3 3/8 inches) above the firebox top, the boiler contains 11 790 l. (2 593 Br. gallons) of water with a steam space of 3 800 l. (134.2 cubic feet).

The large firebox, with its 5 m² (53.8 sq. feet) of grate area, has a large combustion chamber in front of the brick arch; the total length of the box is 3.71 m. (12 ft. 2 in.). The grate is sloped 1 in 6 and has a rocking section as well as a drop section. The total length of the grate is 2.50 m. (8 ft. 2 7/16 in.). The firebox top is uniformly inclined from the tube plate towards the back end and is made of copper with manganese bronze stays. The copper interior side plates are 15 mm. (5/8 inch) thick, the same as that of the steel wrapper plates.

The barrel itself is formed of the usual three courses of steel plates accurately assembled into one another; the thickness of the plates from the trailing to the front course is 22, 22 and 20 mm. (7/8, 7/8 and 35/32 inch) respectively. The thickness of the tubes plates is also 20 mm. (25/32 inch).

The tubes are 6 m. (19 ft. 8 1/4 in.) long; the thickness of the flue tubes is 4 mm. (5/32 inch) and the smoke tubes 2 mm. (5/64 inch). The elements extend the full length of the flues; the degree of superheat (ratio of the superheating surface to the total heating surface) is 37.7 %; the ratio of the section of passage of the combustion gases through the tubes to the air passage through the ash pan is about 61 %.

The smoke box is also very large; it is 3 m. (9 ft. 10 1/8 in.) long; the centre line of the chimney has been moved forward and is 894 mm. (2 ft. 11 13/64

Fig. 2. — Left hand side view of the 2-10-2 locomotive.

in.) behind the smokebox door. The Paris-Lyons & Mediterranean jumper type clover leaf blast pipe with conical spark arrester between the blast pipe top and the chimney is fitted.

The steam on leaving the superheater header is carried down to the bottom of the smoke box in steam pipes bent to large radius curves and on to the H. P. steam chests in horizontal steam pipes. Another pipe on the outside on each side of the engine conveys the exhaust steam from the H. P. cylinder to the corresponding L. P. cylinder and at the same time acts as the intermediate receiver. The exhaust steam from the L. P. cylinders is taken direct to the blast pipe; these pipes are all accessible and are lagged. The sections of these passages are :

H. P. cylinder steam pipes	201 cm^2 (31.15 sq. in.).
L. P. cylinder steam pipes	452 cm^2 (70.06 sq. in.).
L. P. cylinder exhaust pipes	572 cm^2 (101.21 sq. in.).
Capacity of the intermediate reservoir. . .	685 l. (24.2 cubic feet).

The boiler is fed by a Dabeg feed water pump of the well known standard pattern No. 120 B, carried on the left hand side of the engine and driven mechanically off the corresponding crank pin. The water is heated in its mixing chamber which is open to the atmosphere up to 100° C. (232° F.) by part of the exhaust steam from the L. P. cylinders. A standby injector of the U1 type is fitted on the right side behind the steps up to the cab. Both these fittings deliver the water to the boiler through clack valves in the top of the leading course of the barrel. The water falls as a spray on a nest of staggered trays below which the mud collector is carried.

2. Motor.

The 4 cylinders are outside. The L. P. cylinders are carried at the forward end at the customary place and their centres are 2.10 m. (6 ft. 10 11/16 in.) apart; they are horizontal and drive the second pair of coupled wheels, their horizontal centre line being slightly higher than that of the coupled wheels. The two leading pairs of driving wheels are coupled by the usual connecting rods.

The centres of the two H. P. cylinders are 2.20 m. (7 ft. 2 5/8 in.) apart; these cylinders drive the fifth coupled axle, which is coupled to the fourth and third pair of drivers by coupling rods. These cylinders are fitted between the H. P. and L. P. groups of coupled wheels, i. e. between the second and third pairs of coupled wheels. The centre line of these cylinders is inclined 1 in 8 to the horizontal, so as to make it unnecessary to lengthen the spacing of these two pairs of wheels, and thereby the total rigid wheel base. This inclination, whilst insufficient to affect the balancing of the driving forces is moreover corrected by the setting of the cranks.

The second and third pairs of drivers are coupled by inside coupling rods the centre lines being 358 mm. (14 inches) apart in order to maintain the relative position of the two H. P. and L. P. groups of drivers. These rods and the corresponding crank axles have only to transmit forces not exceeding the difference between the H. P. and L. P. forces at any moment considered; these forces although undoubtedly large at times are always much less than those in a single crank axle driven by inside H. P. cylinders. In addition the space available through there being no inside cylinders makes it easy to fit these rods and their brasses and at the same time provide ample room for the axle boxes.

The volume of the H. P. cylinders is 118 l. (4.16 cubic feet), that of the L. P. 305 l. (10.76 cubic feet), so that the ratio of their volumes is 1 to 2.59. Thus 2/3 of the total power of the locomotive can be developed by the H. P. cylinders, and

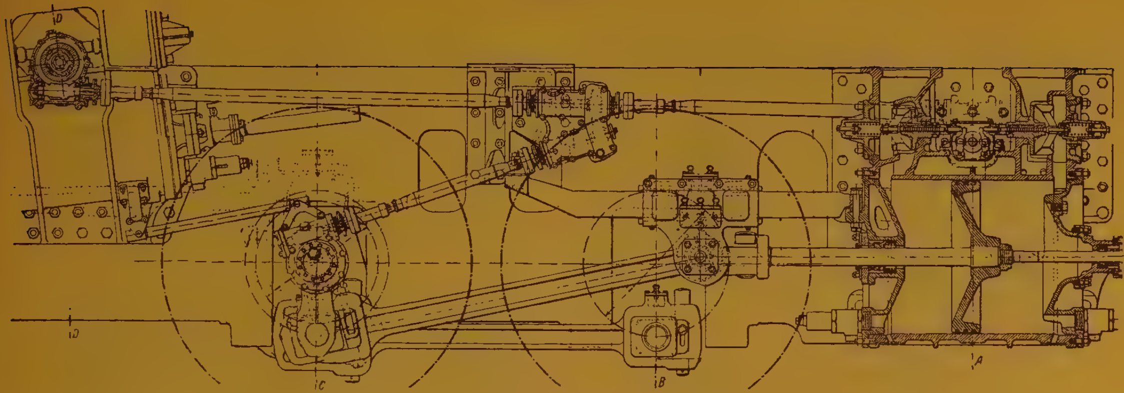

Fig. 3. — Poppet valve gear drive.

the journals of the fifth coupled axle have had to be made stronger.

The cylinders are very rigidly secured to the frame thanks to the transverse box stay which carries them, one such stay being provided for the H. P. and one for the L. P. cylinders. These box girders act at the same time as frame stays; the whole construction is extremely rigid.

The setting of the driving crank pins in a group or between the two groups has been very carefully arranged. On the second pair of drivers, driven by the L. P. cylinders, and coupled to the third pair, the pins on one side (outside and inside) are at 180°, while the two outside crank pins are set at 90° to one another like the motion of the corresponding L. P. cylinders. On the third pair coupled on the one hand to the fifth pair driven by the H. P. cylinders and also to the second pair, the crank pins on one side (inside and outside) are set at 172° 59′ 53″, while the two outside crank pins are set at 90° to one another like the motion of the corresponding H. P. cylinders; in this case the crank pins of one side are not exactly opposite the others, i. e. at 180°, owing to the slope of the H. P. cylinders, although the centres of the L. P. cylinders are horizontal.

The leading dimensions of these different parts of the motion are summarised in the following table :

	H. P. cylinders.	*L. P. cylinders.*
Connecting rods : length	3 m. (9 ft. 10 1/8 in.)	1.900 m. (6 ft. 2 25/32 in.)
ratio : length to throw	9.23	5.428
Inside coupling rods, throw	300 mm. (11 13/16 in.)	
	diameter.	*length.*
Inside coupling brasses	230 mm. (9 1/16 in.)	130 mm. (5 1/8 in.)
Outside coupling brasses :		
1st pair of wheels	135 mm. (5 5/16 in.)	85 mm. (3 11/32 in.)
2nd and 5th pairs of wheels.	210 mm. (8 1/4 in.)	120 mm. (4 23/32 in.)
3rd and 4th pairs of wheels.	135 mm. (5 5/16 in.)	120 mm. (4 23/32 in.)
Crank pin brasses :		
H. P. cylinders	160 mm. (6 5/16 in.)	180 mm. (7 3/32 in.)
L. P. cylinders	130 mm. (5 1/8 in.)	150 mm. (5 29/32 in.)
Driving wheel journals : 1st, 2nd, 3rd and 4th pairs	220 mm. (8 11/16 in.)	280 mm. (11 1/32 in.)
Driving wheels journals : 5th pair.	240 mm. (9 7/16 in.)	280 mm. (11 1/32 in.)

The crank axles (2nd and 3rd pairs of drivers) have been made very strong; the three checks are extended so as to balance the weights very closely. The inside coupling rods are fluted.

The rather high thrusts of the cross heads on the slide bars (due to the small ratio of rod length to throw) are balanced by the large area of the bearing surfaces. Single slide bars are used with the cross heads below.

3. Valve gear.

The builder has fitted the Dabeg Company's « R. C. » type rotary poppet valve gear. The slide valves formerly utilised have therefore been replaced by double seated poppet valves arranged horizontally. The steam passages provided are as follows :

	Admission.	*Exhaust*
H. P. cylinders	254 cm² (39.37 sq. in.)	226 cm² (35.03 sq. in.)
L. P. cylinders	257 cm² (39.84 sq. in.)	347 cm² (53.78 sq. in.)

The dimensions of these poppet valves are as follows :

H. P. cylinders : diameter	180 mm. (7 3/32 in.)	180 mm. (7 3/32 in.)
Maximum lift.	18 mm. (45/64 in.)	20 mm. (25/32 in.)
L. P. cylinders : diameter	195 mm. (7 43/64 in.)	240 mm. (9 7/16 in.)
Maximum lift.	21 mm. (53/64 in.)	23 mm. (29/32 in.)

The valves are operated by a transverse shaft fitted above each cylinder and revolving in synchronism with the driving wheels. This shaft carries a number of cams of varying profile which act on the rollers carried by multiplying levers; it is also arranged to move along its centre line Each multiplying lever drives a button which transmits its movements to the corresponding valve spindle. The amount of lift and the movement of the valves are therefore determined by the profile of the cams in contact with the rollers.

The rotary movement of the cam shafts is taken off both sides of the engine, from the return crank of the second pair of drivers. The gear box driven by this return crank can move freely vertically and laterally following the movements of the axle relatively to the frame; it is, however, limited as regards rotation by an anchoring guide articulated to the H. P. cylinders. The shaft driven by this gear box, which is approximately half way between the two cylinders and by means of pairs of wheels and worms turn at the same angular speed, transmits the motion to two transmission shafts, the second fitted as an extension of the first, driving the gear boxes of the H. P. and L. P. cylinders. These latter gear boxes drive the corresponding cam shafts directly. A helicoidal gear and worm is fitted as in the gear box on the return crank. Roller bearings are fitted throughout. The three driving shafts on each side of the locomotive are fitted with universal joints so as to prevent any undesired stresses being set up. The gears run in an oil bath and dust is prevented from getting into them.

The engine is reversed by moving the cam shaft by means of a hand operated reversing gear which is very smooth in action; the multiplication is 49.3 to 1. The reversing wheel is on the left hand side of the cab and drives through a tubular shaft with cardan joints a longitudinal shaft placed on the centre line between the frame and plates. This latter shaft carries at each end a short lever directly connected to the sleeve of the corresponding cam shaft. The valves are set in the erecting shop and it is not possible subsequently to unduly change their relative positions.

The different cut-offs on this locomotive are the following :

	Forward.	Reverse.
H. P. cyl.	30, 35, 40, 45, 50, 65, 95	40, 50, 95
L. P. cyl.	40, 44, 50, 56, 63, 75, 95	50, 63, 95

There is in addition a special cam to keep the valves open when running with the regulator closed.

This type of valve gear has given excellent results on several engines and is especially suitable when working compound. The variation in the cut-off in the H. P. cylinders should be accompanied by a similar but progressive variation of the L. P. gear. This gradual lengthening of the cut-off is only possible with slide valves when the H. P. and L. P. valve gears are independent and the cut-off used left to the driver. It is then necessary to use an experienced driver who can be relied upon to pay attention to the cut-off the whole time. This is asking a good deal and is open to objection.

On the other hand, the poppet valve gear with rotary cams makes it possible to decide in the shops the relative positions of the H. P. and L. P. valves for the different cut-offs adopted by suitably proportioning the contour and profile of the cams. When the engine leaves the works, the valves have been set once for all; the relative variations of the cut-off in the H. P. and L. P. stages become automatic and will not depend on the driver who is thereby liberated from a fatiguing duty.

In addition to this setting, the driver can, when starting, admit into the low pressure cylinders live steam by a special valve; however, to prevent excessive pressure this steam passes through a reducing valve. As soon as the locomotive attains a predetermined speed the valve closes and the engine works compound.

4. Frame, wheels and axles.

The frame of the locomotive is simplified by there being no inside cylinders; the length of the rigid wheel base and the size of the boiler and the magnitude of the driving forces call for great strength. Except between the 2nd and 3rd pairs of drivers, the spacing of which is 2.25 m. (7 ft. 4 19/32 in.) because of the H. P. cylinders, the spacing of all the coupled wheels is 1.65 m. (5 ft. 5 in.). This gives a total rigid wheel base, H. P. and L. P. units taken together, of 7.20 m. (23 ft. 7 1/2 in.). So that the engine can negotiate curves easily, the flanges of the last coupled wheels are thinned down and especial care has been given to the play of the axles, by this play being as follows :

1st pair of coupled wheels	26 mm. (1 1/32 in.).
2nd pair of coupled wheels	1 mm. (3/64 in.).
3rd and 4th pairs of coupled wheels. .	11 mm. (7/16 in.).
5th pair of coupled wheels	6 mm. (15/64 in.).

The leading truck has a side movement of 116 mm. (4 35/64 inches), and the trailing truck of 111 mm. (4 23/64 inches). The locomotive can in consequence take curves of 140 m. (7 chains) radius.

The frame, and the plates of which are cross stayed by the box girders carrying the H. P. and L. P. cylinders, has in addition cross stays between each pair of drivers and as a whole is extremely rigid.

The frame is carried by laminated springs above the axle boxes, connected by equalisers so that the axle load of each pair of drivers is 18.5 tons. The trailing truck has laminated springs carried under the axle boxes and independent of the springing of the coupled wheels. The leading truck is fitted with coiled springs carried on a bolster parallel to the axle and connected to the centre girder which acts as a compensating lever and regulates the load be-

tween the leading truck and the leading pair of wheels. The side movement of this leading pair of wheels is controlled by swing links whereas the side control of the trailing truck depends upon inclined planes.

Fig. 4. — General arrangement of the Dabeg « R. C. » valve gear.

The springs have the following characteristics :

Coupled wheels : 17 plates; flexibility 6.31 mm. per t. (0.255 inch per Engl. ton).

Trailing truck : 12 plates; flexibility 4.31 mm. per t. (0.174 inch per Engl. ton).

Leading truck : coiled springs; flexibility 4.43 mm. per t. (0.179 inch per Engl. ton).

5. Miscellaneous equipment.

This goods engine intended for working heavy goods trains over steep gradients is fitted with the Westinghouse automatic brake specially designed for goods trains with two-stage compound air pumps. The brake blocks are carried on the trailing side of the coupled wheels. The driver can also use the back pressure brake in the H. P. and L. P. cylinders simultaneously.

Sand can be supplied on both sides of the engine in front of the 5th pair of drivers and behind the 4th pair, driven by the L. P. cylinders. The sand boxes are steam operated and are built round the steam dome, the whole being covered by the same clothing which has simplified and improved the profile of the top of the boiler.

The regulator worked by outside rods is of the double ported type. There are 2 directly loaded safety valves 100 mm. (3 15/16 inches) in diameter; they are fitted with silencers. The steam cylinders are fitted with blow-off valves as well as with hand operated cocks.

The cylinders and different parts are lubricated by a Wakefield pump with 14 feeds fitted with an anticarboniser.

The cab with all its gear is well arranged. The different auxiliaries are supplied with steam from a common supply pipe connected to the steam dome and is fitted with a main shut off valve.

Among the special fittings may be mentioned :

— Fire hole door with adjustable opening;

— Electric lighting of the train by turbo-generator;

— Train steam heating;

— Pressure gauges, one double and one triple type showing the pressure in the boiler and the H. P. and L. P. steam chests;

— Flaman speed recorder;

— Danger signal indicator and recorder.

The tender is of the Paris-Lyons & Mediterranean type carried on two four-wheeled bogies. It carries 28 tons of water and 7 tons of coal to suit the relatively short distances between stops.

This type of locomotive, ten of which have been delivered, belong to the new 151 A class and are intended for working heavy goods trains over difficult sections. It should show appreciable fuel savings, as well as being easier to maintain and simpler to use in service, with its large draw bar pull. This engine should be followed with attention as it represents in the clearest manner possible the ideas held on the Paris-Lyons & Mediterranean Railway.

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The new « Mountain » type locomotive
of the
French State Railways,

by Henri MARTIN,
Ingénieur des Arts et Manufactures.

(*Le Génie Civil.*)

The French State Railways recently exhibited in Paris in the St. Lazare station a *Mountain* type locomotive of greater power than the engines of the same type in service at the present time on other French railways. This new locomotive is the prototype of a new series the State Railways intend to build if the results obtained conform with those expected.

It will be remembered that the first *Mountain* type locomotive (a four-wheeled bogie at the leading end, eight coupled wheels, and a trailing two-wheeled truck) was put into service by the Paris-Lyons-Mediterranean Railway on the Laroche-Dijon line, which climbs continuously between Laroche and the summit tunnel at Blaisy-Bas. These engines appreciably improved the traction conditions on this difficult section, the length of which is 159 km. (98.8 miles (1).

The Est Railway then carried out a long series of trials with another *Mountain* type locomotive designed and built in its own shops which had in particular larger coupled wheels (1.95 m. = 6 ft. 4 25/32 in. instead of 1.79 m. = 5 ft. 10 15/32 in.). After tests on the Est, lasting over two years, this engine was in 1929 lent to the State Railways who tested it on the Paris-Cherbourg line with a view to hauling boat trains weighing 600 tons (2). These tests showed that more than half an hour could be made up on the Paris-Cherbourg run (four and a half instead of five hours). As a result of these favourable results, the State Railways built a number of engines of this type and these are in service at the present time.

The new *Mountain* locomotive (figs. 1, 2 and 5) we are about to describe will make it possible, it is expected, to reduce

(1) See the article on this subject, by Mr. Parmantier, in the *Revue Générale des Chemins de fer*, September 1932.

(2) See the article on the Locomotives at the Liége Exhibition, in the *Génie Civil* of the 3 January 1931.

Fig. 1. — New *Mountain* type locomotive of the French State Railways.

the present timing by half an hour, i. e. to four hours without intermediate stops.

The principal differences between the present State *Mountain* locomotives and the new are in connection with the following points : increase in the evaporative power of the boiler, use of three cylinders, simple expansion, with Renaud system poppet valves.

Boiler. — In order to ensure the speed

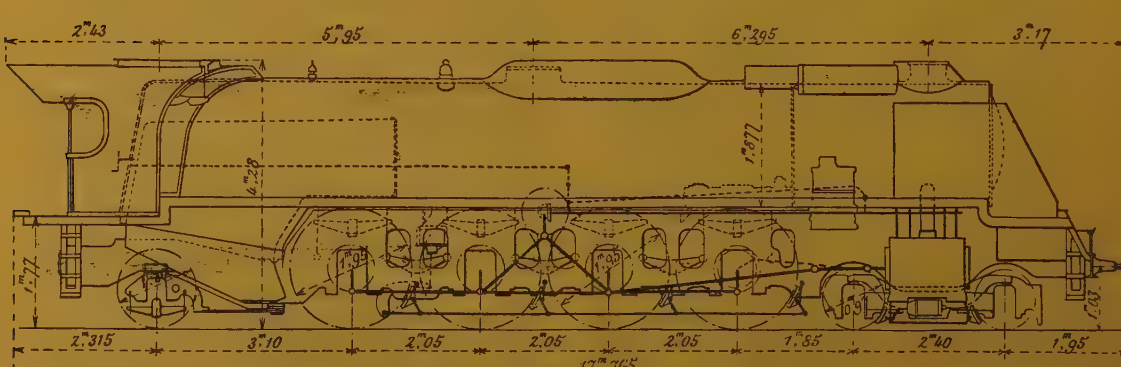

Fig. 2. — Diagram of the *Mountain* type locomotive of the French State Railways.

being maintained on the up gradients, the steam production had to be greater than that of the present *Mountain* locomotives. It is calculated that the Paris-Cherbourg run involves the evaporation of 50 m^3 (11 000 Br. gallons) of water. To evaporate this quantity of water in the time available the total heating surface was increased from 217.60 m^2 (2 342 sq. feet) to 278.35 m^2 (2 996 sq. feet) and the grate area from 4.43 m^2 (47.7 sq. feet) to 5 m^2 (53.8 sq. feet). A combustion chamber at the front end of the firebox has been retained so that the volatile matters can be completely burnt before passing into the tubes. This combustion chamber between the grate and the tubes is not a novelty as it is used on the *Mountain* locomotives of the Paris-Lyons-Mediterranean, the Est and the State Railways.

The superheating surface is on the other hand slightly less than on the *Mountain* locomotives now in service; it has been reduced from 92.57 m^2 (996 sq. feet) to 85.65 m^2 (922 sq. feet). The boiler pressure is 20 kgr. (284.4 lb. per sq. inch) as on the present State, and Est *Mountain* locomotives. The first engines of this type built by the Est had only 16 kgr. (227.6 lb. per sq. inch) pressure which was raised to 20 kgr. on the second batch built.

The height of the boiler centre line above the rail has only been increased by 1 cm. (3/8 inch) to 2.95 m. (9 ft. 8 5/32 in.).

The most original feature of the new locomotive lies in the use of an automatic stoker.

Hand firing would have been too trying for one fireman, as he would have had to fire about 2 tons of coal an hour

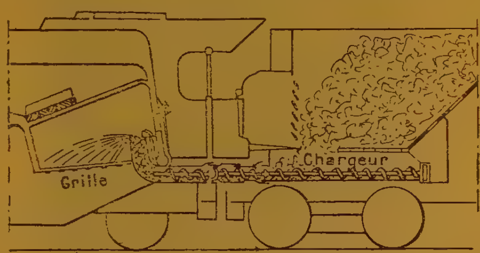

Fig. 3. — Diagrammatic section showing the mechanical stoker.

Note : Grille = Grate. — Chargeur = Stoker.

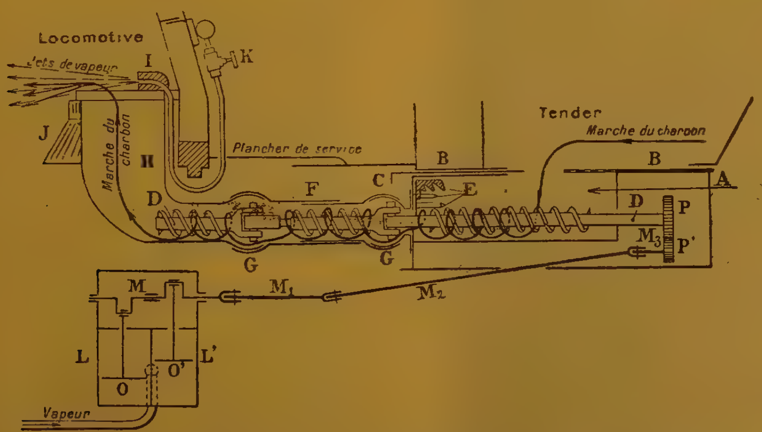

Fig. 4. — Detailed diagram showing the arrangement of the stoker.

Explanation of French terms : Jets de vapeur = Steam jets. — Marche du charbon = Course followed by the coal. — Plancher de service = Footplate. — Vapeur = Steam.

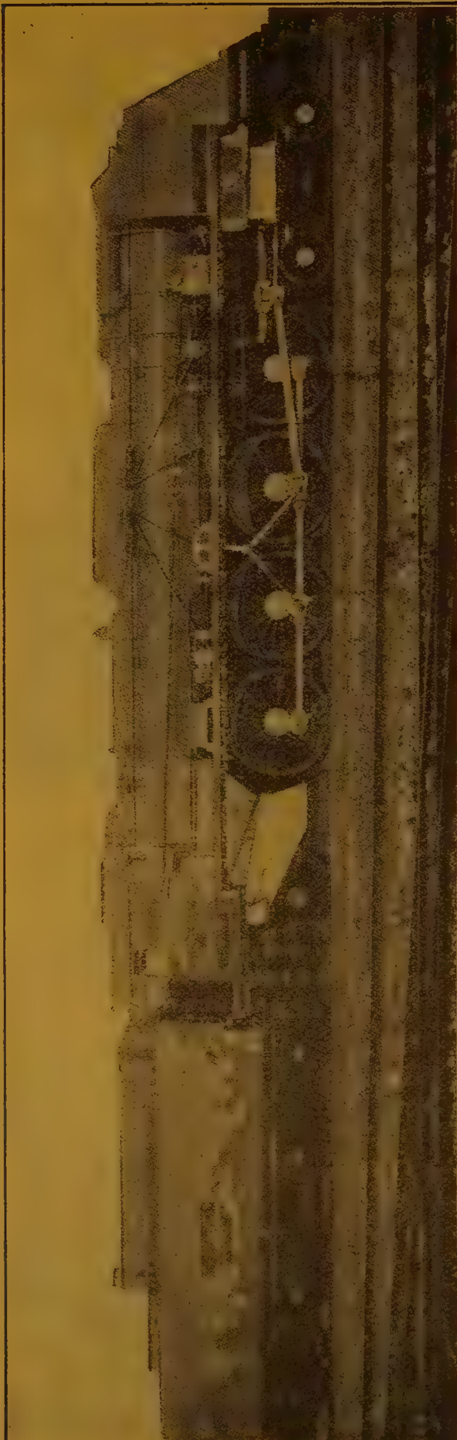

Fig. 5. — New *Mountain* type locomotive of the French State Railways.

equal to firing 50 kgr. (110 lb.) every minute and a half. It was thought better to fit a mechanical stoker of American origin of which only a few are in use in Europe at the present time (fig. 3).

The coal falls by gravity into a trough A (fig. 4) fitted below the bottom of the coal bunker B. Sliding shutters C enable the quantity of coal admitted into the trough A to be regulated.

A screw D in cast steel, known as a conveyor, fitted in the trough A, brings the coal to the forward end of this trough where it meets about in line with the top of the trough a crusher plate E against which the large lumps are broken up.

The screw D is continued forward under he foot plate by a telescopic section with the ball joints G at its two ends so as to take care of the relative movements of the engine and tender.

The coal is elevated by the screw conveyor in the pipe H in the firebox. At the top of this pipe are placed the distributor parts I for feeding the coal over the grate. The pipe is protected from the fire by the vertical bars J through which air circulates. The coal arriving at the top of the pipe H is distributed over the grate by means of pressure steam jets. The pressure of these steam jets is adjusted by means of 5 valves K on the back plate, handy to the fireman.

The screw D is driven by the toothed wheels P and P', one keyed to the screw D and the other to the articulated shaft M, M^1, M^2, M^3 by three cardan joints. This latter shaft is rotated by the two pistons O and O′ moving in the two steam cylinders L and L′. Steam is fed to these two cylinders, fitted below the foot plate of the locomotive, through a valve on the steam piping.

The work of the fireman on a stoker fired locomotive is considerably reduced. He has only to operate a number of steam valves to vary the speed of the conveyor screw to bring forward more or less coal and to regulate the strength of the steam

jets to ensure the coal being properly distributed over the grate.

It should be noticed that the barrel is of special nickel steel to reduce the weight and that the firebox is fitted with an arch carried on water tubes.

The firebox is copper and its length at the top is 1.915 m. (12 ft. 10 5/32 in.); the firebox stays are of manganese bronze. The boiler is fitted with directly loaded silent safety valves. The tubes are 6.30 m. (20 ft. 8 in.) long between tubes plates. There are 30 flues of 140/148 mm. (5 13/64 in. — 5 53/64 in.), 20 smooth tubes of 50/55 m. (1 31/32 in. — 2 11/64 in.) and 91 partly ribbed tubes of 65/70 mm. (2 9/16 in. — 2 3/4 in.) diameter.

The superheater consists of 30 elements of 31/38 mm. (1 7/32 in. — 1 1/2 in.) diameter.

The boiler is fed by a pump with heater; in addition two injectors are fitted in reserve.

The firebox door is in three sections G, one of which can be set. The regulator is the Est valve type. The water gauges are of the reflex type; the blast pipe is of the adjustable clover leaf type.

Frame. — The engine, like the previous one, has driving wheels 1.95 m. (6 ft. 4 25/32 in.) diameter. The bogie and trailing truck wheels are 0.973 m. (3 ft. 2 5/16 in.) and 1.30 m. (4 ft. 3 13/64 in.) respectively. As we have already said, the new locomotive is noteworthy by the fact that compounding using four cylinders has been given up in favour of the three-cylinder simple expansion design.

This arrangement has only been made possible by using a poppet valve gear with which it is possible to get a much greater opening and shutting of the valves than with the classic arrangement of piston valves. It is in this way possible to properly expand the steam from the admission pressure of 20 kgr. (284.4 lb. per sq. inch).

Locomotives with three cylinders at 120° are in use on the Est Railway at the present time. These are suburban tank engines; the crank being at 120° these engines are particularly good at starting, as required by this special service. The State has also applied the system to a series of powerful goods locomotives working mineral trains from Briey.

The new *Mountain* locomotive of the French State Railways is, however, the first example of the use of three cylinders and simple expansion to eight coupled locomotives for hauling express trains. The advantages and disadvantages of abandoning the compound arrangement will only be known after a long period of tests.

We will not come back to the Renaud valve gear, as a full study of such systems of valve gears using poppet valves on locomotives appeared in the *Génie Civil* of the 4 April 1931.

The main feature of the valve gear is, it will be remembered, the use of a valve shaft with drums fitted with cams, the projection of which varies during the revolution according to a given law. These cams open and shut the valves through spring loaded rockers (fig. 6).

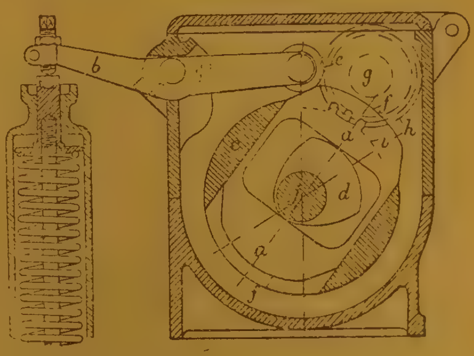

Fig. 6. — Cross section of the valve box and of a drum, Renaud system.

a) Cam carrying link and its rectangular cage; *b*) Rocker; *d*) Fixed triangular eccentric; *e*) Drum driven by the wheels; *f*) Cam; *j*) Shaft controlling the motion.

The variations in cam throw are produced in the following manner. Each cam forms part of a link which moves in the corresponding drum. At the centre of the link there is a rectangular opening inside of which there is a triangular eccentric keyed on a shaft which is locked during running. The rotation of the cam, constantly tangent to this immobile triangular eccentric, causes it to make a series of displacements in the slides of the drum.

The triangular eccentric can take up a number of different positions when the driver turns the shaft to which it is keyed. He can in this way regulate the degree of admission by means of the reversing gear according to the work to be done. He regulates in this way the opening and the closing of the cylinder ports, and can work forward or back as he wishes.

The Renaud gear, moreover, has been tested over a long period on a *Mikado* type locomotive the State Railways exhibited at the Liége Exhibition. Comparative tests with locomotives with piston valves of the same type showed the superiority of the poppet valve engines. The indicator diagrams showed the rapidity of opening and closing of the admission and exhaust valves, as well as the constancy of the phases of admission and of preexhaust. A saving of fuel exceeding 9 % was also obtained.

The outside cylinders are 0.53 m. (20 7/8 inches) in diameter, with a 0.76-m. (29 7/8 inches) stroke. The inside cylinder has a diameter of 0.57 m. (22 7/16 inches) and a stroke of 0.65 m. (25 5/8 inches). The cylinder volumes are therefore 168 and 166 l. (5.93 and 5.86 cubic feet) respectively.

The outside and inside cylinders drive the second and first driving axles respectively. This latter, which naturally has a single crank balanced in itself, is stronger than the double throw axle of the usual type. It has in fact been possible to make this single throw crank such a size as to make it much stronger. In addition, as it is balanced in itself, it has been possible to reduce the counterbalance weights in the wheels.

The cross shaft, which transmits through bevels the motion to the two valve shafts, is driven by a crank driven in turn by a rigid triangle formed of two inclined rods articulated on two successive pins of the side rods on the right hand side of the engine. On the left side there is no valve gear other than the longitudinal shaft controlling the valves which is, however, invisible from the outside. The lubrication of the cylinders and axle boxes is by means of pumps. The result is a great simplification of the lubrication, especially as there are no slide valves in the Renaud design.

The cab of the new *Mountain* locomotive is of the wind cutter form which distinguishes it from the locomotives now in service. The vertical plates preventing smoke beating down onto the boiler top have been lowered so as to lighten the appearance of the engine. The chimney can only just be seen as it is enclosed inside a plate inclined towards the rear.

In the same way the dome and the sand box are enclosed in a single casing in sheet metal.

The weight of the locomotive in running order is 128 t. (125.9 Engl. tons). The theoretical tractive effort is 33 346 kgr. (73 515 lb.) and the calculated power 2 766 H.P.

Tender. — The tender (fig. 7) also has a number of interesting features. It is carried on roller bearing axle boxes which have so far been fitted to carriages only. The result is easier starting and less risk of running hot.

The water tank is almost entirely welded, so as to reduce the weight as compared with riveted construction. It carries 34 m³ (7 483 Br. gallons) of water and 11 400 kgr. (25 130 lb.) of coal.

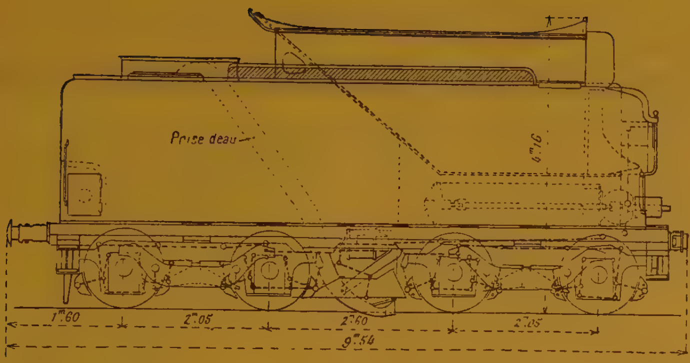

Fig. 7. — Tender elevation.

Note : Prise d'eau = Water scoop.

The total weight of the tender in running order is 78 200 kgr. (76.9 Engl. tons).

This tender is fitted, like all tenders for express engines on the State Railways, with pick up gear for picking up water front 500-m. (546 yards) troughs. The 34 m³ (7 483 Br. gallons) of water would not be enough for such a run as Paris - Cherbourg without intermediate stops.

This pick up is worked from the cab by compressed air, whereas previously hand operated lever gear was fitted. The only precaution taken is to reduce the speed to 60 km. (37.3 miles) an hour when lowering the scoop into the through. The compressed air control makes the work much easier for the fireman, whose duties are becoming much more like those of the driver.

It should also be noted that electric light is supplied from a turbo-generator fitted on the locomotive.

The new *Mountain* type locomotive of the French State Railways has been designed to meet the requirements of this Company by the O. C. E. M. (Office Central d'Etudes de Matériel de Chemins de fer). It includes a number of interesting features such as the abandonment of compounding and the adoption of poppet valve gear by which full advantage may be taken of the expansion of the steam.

It will be interesting to hear at a later date the results of the tests to be undertaken by the State Railways as compared with the *Mountain* type locomotive now running in regular service.

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The aerodynamical resistance of railway vehicles,

by MAURICE ROY,

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(*Bevue Générale des Chemins de fer.*)

The *Revue Générale,* in the July 1932 issue, published an article by Mr. Leboucher, Ingénieur en chef des Services Techniques du Matériel et de la Traction, French Midi Railway, on certain *Aerodynamical trials in connection with the exterior form to be given rail motor cars* (1).

The test method followed consisted in the use of reduced scale models in an aerodynamical flume, a method especially developed up to the present in connection with aircraft manufacture.

The problem so presented is of major interest in the case of rail motor cars intended as a rule to run as single units, as the air resistance is the preponderating factor in the energy used for driving purposes at high speeds [exceeding 60 km. (37.5 miles) an hour for example].

Returning to the question raised by the above mentioned investigation and to the experiments reported in conjunction therewith, we propose to make some observations on the subject, based on the actual state of progress in the mechanics of fluids, both theoretically and applied, and on a long experience of the interpretation of aerodynamical tests.

Having devoted ourselves for a long time to the technical improvement of railway locomotion, we will endeavour more especially to bring out the positive side of the problem, both as regards the results established and as regards the methods to be used to develop or improve these latter.

(1) Cf. also *Bulletin of the Railway Congress,* page 219 of the February 1933 issue, wherein this article was reproduced from the *Revue Générale.*

I. — Aerodynamical forces acting on railway vehicles in motion.

The aerodynamical forces acting on a moving vehicle increase the energy consumed in three ways :

a) through the resistance consisting of *the projection, along the line of movement, of the resultant of the aerodynamical forces in action;*

b) through the *resisting couple* by which the aerodynamical forces acting on the parts in motion, and in particular on the wheels, opposes the motion proper of these parts;

c) through the *alteration of the frictional reaction at the rail* as a consequence of the modification under the influence of the aerodynamical forces of the way the vehicle is carried on the rail (position, direction and load).

The result of the above is that the expenditure of energy required for propulsion within a fluid cannot be determined when only the resistance properly speaking, i. e. of the resultant reaction opposed to the general movement of the vehicle, is taken into account.

It is therefore not sufficient to study theoretically or experimentally this single « resistance » to be in a position to determine the best outside form of the vehicle under consideration.

It should also be remembered that an investigation of this kind always supposes that *constant working conditions* are established in the movement of the fluid relatively to that of the vehicle in motion.

The actual working conditions are, however, usually widely different from this ideal state of affairs.

In the case of railway vehicles, the speed of which is not very high [always less than 120 km. (75 miles) an hour], the movement of the atmosphere itself changes to an appreciable extent the relative motion of the air. The topography of the railway line and the variability of the winds encountered also multiply the causes of disturbance, so that a constant flow of the air about the vehicle in question is rarely, if ever, experienced.

In addition to the above causes of disturbance which are of an accidental nature, there is one which acts systematically (1), i. e. the varying profile with its periodical changes in surface of the ballast broken, for example, by the sleepers at regular intervals. This factor alone is sufficient to make it impossible to obtain constant working conditions in the exact meaning of the phrase.

The aerodynamical forces acting on a moving railway vehicle should, therefore, be dealt with by considering all their factors affecting the expenditure of driving energy; they are, moreover, subject to various and more or less fortuitous fluctuations.

This remark which affects *the very foundation of the problem* shows *a priori* that the investigation into these actions is necessarily a rather complex one and that, in carrying it out, care should be taken to separate the rather numerous variables upon which their actions depend.

The true importance of certain experiments, tried for example in an aerodynamical wind flume, is in consequence much reduced, while trials carried out under actual running conditions can usually only give *average figures;* at the same time as these values are recorded the average values of the principal parameters peculiar to the trials should be noted in each case.

Having recorded these reservations of principle, we will limit ourselves for the sake of simplicity to considering the hypothetical case of constant working conditions whilst running on the straight and, again for simplicity, of a single motor vehicle, the outside mechanism of which has a rotary motion only.

This vehicle naturally being symmetrical in the vertical plane parallel to the centre line of the track, its speed in parallel with this centre line lies in this plane.

We have to suppose also that the movement of the atmosphere itself is uniform and parallel to the plane of the rails.

In the *simplified* case so presented, the aerodynamical actions at each point of the vehicle depend solely upon the parameters which determine :

the magnitude of the general speed of the relative air current, the resultant of the speed of the vehicle itself and of the absolute speed of the natural wind;

the direction of this speed relatively to the vehicle, defined by its *incidence* or angle included between this speed and the longitudinal axis of the vehicle;

the speed of rotation of the revolving parts;

that is to say only three variables.

Dividing the vehicle into its fixed and

(1) In the same way, in the case of a vehicle with reciprocating mechanism exposed to the air, the movement of this mechanism necessarily imposes a periodic character on the possible aerodynamical working conditions.

revolving parts, the resultant and the resultant moment of the aerodynamical forces on each of these parts are calculated from their three components on, for example, the three classic reference axes of the vehicle, *rolling* (or longitudinal), *pitching* (or transverse), and *hunting* (or perpendicular).

If the natural or absolute wind has no transverse component (head on or following), the resultant lies in the axial plane of the vehicle, while the moments are at right angles thereto.

If the wind has a transverse component, all the components of the resultants and resultant moments have as a rule values which are other than nil.

Considered as a whole, the three main factors to be taken into account are :

a) *axial resistance*, the geometric sum of the components on the rolling or longitudinal axis, i. e. following the running speed, of all the aerodynamical actions;

b) *resisting couple* due to the friction of the surrounding air on each revolving part (wheels and axles, or wheels if the axle is fixed);

c) *alteration in the support and the wheel load on the rail.*

When we look into this last factor, we raise a number of rather intricate problems. The body and the frame of the vehicle can, as a result of the aerodynamical forces, be forced sideways by a transverse force, be raised or lowered by a force acting at right angles (or vertically) unequally or not on the different wheels, according as there is or is not a rolling couple or hunting couple.

The rolling friction on the rail, or at the journals, is in this way modified unequally or not on the different wheels, and it is difficult to appreciate the resulting variation in what is called the « rolling resistance ». *The question is sufficiently important for it to be thoroughly investigated experimentally.*

In view of our present ignorance of the subject we must be content to ignore the third of the three factors mentioned above and devote our attention to the other two : the total axial resistance and the resisting couple of the revolving parts.

Very little is in fact known about the latter factor. In aviation, the only field in which aerodynamical tests have been widely developed, attention is only given to the axial resistance or « drag » of the landing wheels as these during flight do not turn or are sometimes pulled round slowly by the current of the surrounding air. In addition, we have some data especially in connection with the drums and discs of turbines, on the rotary resistance of revolving solids in contact with a fluid, but it is then a question of a fluid not carried along by a general current.

We can, however, consider as certain that the rotary resistance of some wheels such as motor car or railway rolling stock wheels at high running speeds, when the rotation and translation are both fast, is high, as the wheels are scrubbed by the atmospheric air.

The turbulence so set up, in addition, disturbs the general flow past the adjacent solid bodies and increases more or less the axial resistance of the whole of the fixed and revolving parts of the vehicle.

This important remark shows that it is not sufficient to investigate, even experimentally, the longitudinal resistance of a vehicle in terms of its speed of translation whilst leaving immobile, for convenience in making the tests, the parts which actually have a high rate of rotation. *The investigation of this longitudinal resistance should be made by reproducing the translatory and rotary movements which together determine the real form of flow of the air about the vehicle.*

Finally, as regards the longitudinal resistance of the fixed parts of the vehicle (body, frame and various fittings) it

must be noted that this total resistance forms a whole which ought not to be divided into parts arbitrarily.

Let us be quite clear on this point. In the article to which we refer, the author distinguishes between the « resistance of penetration » of a locomotive through the air based on the results of the Marienfelde-Zossen tests (1903) in which the front end of the locomotive was free to move against the dynamometer supporting it. The resistance arrived at in this way depends upon the *complete form* of the vehicle as a whole and of any vehicles attached behind it. This is due to the interdependence, as regards aerodynamical actions exerted at each point or on some area by the surrounding air current, of all the elements which together form the whole form. This principle, which corresponds to *the impossibility of there being any elementary law of the resistance* of a given solid moving in a fluid, today dominates the execution and interpretation of all aerodynamical experiments affecting aviation.

What we have to consider is the total resistance of a complete body, and if this vehicle is attached to others, the resistance of them all as a whole, which resistance is never and cannot be the sum of the individual resistances.

II. — Aerodynamical tests on reduced scale models.

As we all know, these tests in wind flumes are largely used today in thé aircraft industry, just as similar tank tests have been undertaken increasingly in ship building.

The many investigations based on these tests have brought out the importance of having like conditions if the tests on models are to be transposed to full size according to a known and sure method.

In the aerodynamical tests and for speeds applicable to railway vehicles, the two essential conditions to be fulfilled are, for the reduced scale model and for the actual vehicle :

a) On the one hand, ***absolute similaritiy of the outward shapes and of the movements;***

b) On the other hand, ***identity of the corresponding Reynolds numbers,*** this number R being the ratio of the product of the speed by a length characteristic of the kinematic viscosity of the fluid.

Let us consider these two points in the case of trials like those reported in the *Revue Générale*, in the article already quoted.

a) To have similarity of the shapes and of the movements there must be perfect reproduction *in all details* of the vehicle and of the track, as well as in the rotation of the revolving parts with a suitable movement of translation of the reduced scale track under the model of the vehicle held stationary in the wind stream in the flume.

It is impossible to carry out such a programme, and the difficulties preventing it are easily appreciated.

When the experimental equipment is simplified to any great extent, as has been done in the tests in question, we depart *in so many points* from the close observation of the above enunciated condition that the problem as examined differs very deeply from the real one. As to the importance of the differences or errors introduced in this way, it cannot be calculated, but it corresponds to *an underestimation, probably to a quite considerable extent, of the factors relatively to reality.*

We would in particular stress the fact that the method known as the « method of images » of measuring the resistance by means of a double model formed by a simplified reproduction of the vehicle and its duplicate arranged symmetrically to it underneath the imaginary plane representing the ground, only gives a rough idea of the double of the resistance of the isolated vehicle relatively to the ground. In this method there is no ac-

tual reproduction of the ground and the movement of the air in the plane of symmetry of the double model in no way corresponds to the actual movement of the fluid in contact with the ground under the single vehicle. In actual fact, owing to the special pecularities of the surface of the ground, the current of air rolled out along the ground by the passage of the vehicle has its own special turbulence with periodical vortices which influence to an appreciable extent the flow of air round about the vehicle itself, and all the resulting aerodynamical actions.

b) The second condition of similarity, like the first, cannot be obtained.

The small model acting in the air like the actual vehicle under almost identical conditions of temperature and pressure, the denominator of the Reynolds number R is the same in the two cases, whereas the numerator of R cannot be alike in the two cases.

The scale of the model being of the order of 1/20 to 1/50 of the full size, the test speed in the flume should in fact be 20 to 50 times the actual, whereas in practice it cannot exceed 120 to 150 km. (75 to 93 miles) an hour, although the aerodynamical resistance of the vehicle at such actual speeds is precisely what has to be investigated.

The reduced scale model is thus worked with at a value of R much below the real one, and to transfer to the actual vehicle the results obtained with the model, the variation of the aerodynamical constants with the value of R must be taken into account.

We are caught in a vicious circle since to know the variation of these constants when passing from the value of R corresponding to the test to that of the actual vehicle it is necessary to know in this latter case these constants, whereas we endeavour to calculate them from the test with the reduced scale model.

The same difficulty arises, it should be noted, in aviation for analogous reasons. So far it has been solved as well as may be by taking into account certains factors ascertained on the evolution of the resistance in terms of R in a number of typical cases in which it has been possible to test experimentally, especially in flumes with very high currents or in closed circuit flumes in which the air pressure is 10 to 20 atm. (142 to 284 lb. per sq. inch) and by making certain adjustments by means of flying tests during which an endeavour is made to arrive at the real magnitude of the coefficients of the actual vehicle.

In spite of the work done in this way, the transfer to an actual flying machine of the results obtained with the model contains probable causes of error which it is tried to avoid more and more by using *large powerful flumes* in which the tests are made on models of *a scale close to full size.*

However expensive this method may be it has so many advantages that for aircraft work its use has become essential.

When such flumes are at the disposal of engineers, their use in connection with the problem with which we are dealing can also be considered at all events for the single vehicle provided its length is not excessive. The difficulties in the way of reproducing as a model the ground in movement and the rotation of the revolving parts will subsist however and therefore it will only be possible to carry out a partial investigation of the problem.

A few words may be added usefully to fix our ideas on the meaning, as regards the value of the resistance constants, of the Reynolds number R.

Below a certain value of R, *the critical value* and in the case of solids with reasonably good aerodynamical qualities and of various shapes, these constants vary with R in a more or less differing and irregular way. On the other

hand above the critical value, the variation is more regular and almost constant. Moreover when R is sufficiently great, the falling off in value of these constants relatively to R ceases almost entirely.

The critical value of R, which is independent from the units as R is an expression without dimension, is of the order of 10^5 to 10^6 when the obstacle is of *simple form*. Consequently for ordinary air, the coefficient of kinematic viscosity of which is of the order of 0.13×10^4 m²/sec., the critical value of the product VL (speed in metres per second multiplied by the length in metres in the direction of the current) is of the order of 1.3 to 13 approximately.

A vehicle 10 to 20 m. (33 to 66 feet) long, therefore, at speeds exceeding some metres per second, is much above the critical value of R corresponding to a solid of a simple form comparable to its general form.

On the other hand, a model 0.40 to 0.90 m. (1 ft. 3 3/4 in. to 2 ft. 11 1/2 in.) long — like the models used in the tests considered above — falls in the zone of the critical values of R when the speed of the wind in the flume is 3 to 30 m. (9.84 to 98.4 feet) per second) or 1.5 to 15 (4.92 to 49.2 feet) per second, *which is precisely the field of the tests we are concerned with.*

There is, however, more than this and the presence of small surface irregularities and projections which are found in very large numbers on actual railway vehicles brings into play for a solid of complex form a critical value of R very different from that corresponding to the solid of simple form free from any small surface irregularities and projections exclusively considered above.

Let us take for example a small look-out projecting above the roof, its length being 1/1000th of that of the vehicle. On a 1 in 20 model, i. e. 1 m. (3 ft. 3 3/8 in.) long, the reproduction of the look-out would form a projection 1 mm. (0.039 inch) in length. Let us suppose that the critical value of R be 10^5 for the body of the vehicle by itself (reduced to a simple form with the surface smooth all over) and 10^6 for the separate reproduction of the look-out, and let us test models in the flume with a wind of 20 m. (65.6 feet) per second.

If each of the elements were *separate,* we should find in the tests and on the actual thing at the same speed under the following conditions of the product VL relatively to the corresponding critical value :

	Value of VL in m²/sec.		
	Critical.	Test.	Actual.
Vehicle . . .	1.3	20	400
Look-out . .	1.3	0.02	0.4

The coefficient of resistance of the first would in both cases lie above its critical value, whereas the opposite would be the case for the other. When passing from the model to the actual vehicle, these coefficients would change in a regular manner in the case of the former and in an irregular way in that of the latter.

In addition, for the two elements united together, as in the actual vehicle, the coefficient of the total resistance will alter when changing from the model to the actual vehicle in a totally unforeseen manner.

In order to avoid this difficulty, which has been recognised for some years, the models of air craft tested in the air flume do not reproduce the small surface irregularities nor most of the projections of the full size vehicle. Special tests are made using larger scale separate models to ascertain the actual resistance of the projections. The addition of the partial resistances so arrived at should be made while taking into account the effect known as *interaction* between the different factors supposedly united together as in the actual vehicle. It is quite true that today a certain amount of accurate information has been collected on this subject, but only as regards certain parti-

cular cases and especially for projections very well stream lined individually, and *which do not appreciably alter the flow of air round the principal solid body.*

This is not so in the case of the railway vehicle. The surface irregularities, whether projections or hollows of the outside surface, are many and varied, the fittings or auxiliary obstacles are also many and are difficult to stream line individually (wheels and axles, brake rigging, bogie frames, driving gear under the frames, brake equipment, etc.).

The whole of the above remarks definitely lead to the following general conclusion : *that tests on simplified small scale models in the ordinary flume and without adequate reproduction of the ground nor of the rotation of the revolving parts of the vehicle — tests such as those considered above — can only give very approximate ideas on the aerodynamical properties of the actual vehicle, and in addition that these properties can only be appreciated with any degree of exactitude, starting from the results of such tests, no acceptable method of transposition having as yet been divided.*

The most that can be expected from comparative tests carried out under such conditions is some information, unfortunately uncertain, on the *comparison* between like full size models.

III. — Notes on the results of the tests carried out on behalf of the French Midi Railway.

The general remarks given above considerably restrict the importance and meaning of the tests made in November 1932, in the wind flume of the Aeronautical Technical Services at Issy-les-Moulineaux on behalf of the Midi Railway, the results of which tests were given in the article to which we have referred.

These tests enable us to make the following more precise remarks as regards details :

a) *Experimental layout.*

The *fixed floor,* originally placed below the model has given bad results, and has rightly been given up as it did not correspond, neither by its form nor its immobility relatively to the model, with a true reproduction of the actual ground.

The *method of images* with a double model subsequently tried in place of the methods using a fixed floor does not correspond any better to the actual ground conditions, but still to some extent it does make it possible to obtain a valuable indication upon the point whether it is better to stream line to a cylindrical form with its generating lines parallel to the ground or at right angles to it, a vehicle whose bottom surface moves in proximity to a limiting surface (the ground) against which this surface rolls out the current of air below it. Under the condition of the tests considered, the second system (model C) gives an appreciably lower resistance than the first (model B) and this indication should be remembered without it being necessary to attach any other importance to the numerical value of the comparative ratio obtained from these tests.

Moreover, the relatively high resistance of the supports of the models, even when investigated by weighing tests, *considerably alters the accuracy of the measurements of the resistances of the models themselves.* Slight differences between two resistances measured under such conditions cannot therefore be interpreted in any way.

b) *Influence of a stream lined look out projecting above the roof.*

The tests showed this influence to be small. In accordance with the previous remark, no conclusion can be drawn from this simple observation.

Moreover, the remarks already made

as to the influence of the Reynolds number are sufficient to take away, as regards the full size model, any meaning from the result obtained with the reduced scale model.

In addition, there is good reason today to estimate that a *well stream lined* and closed-in look out ought not to cause in practice an appreciable increase in resistance contrarily to what the result of the Issy-les-Moulineaux tests appear to show.

c) *Influence of the length of the vehicle.*

According to the tests we are considering a rail car like the model A would have an appreciably constant resistance for a length of 14 to 19 m. (45 ft. 11 in. to 62 ft. 6 in.) and a cross section of 8.60 m² (92.6 sq. feet). The exactitude and precision of the resistance curves [at constant speed and cross section and for a vehicle length of 13 to 25 m. (43 to 82 feet)] shown in figure 11 of the previously quoted article are doubtful for the reasons already shown and their form with a double projection is abnormal, the resistance again appearing to decrease when the length exceeds 25 m. (82 feet). This paradoxical result should undoubtedly in our opinion be attributed to the already mentioned defects in the method employed when making the tests.

It will have been noted that these tests have been made on models 0.39 to 0.76 m. (1 ft. 3 3/8 in. to 2 ft. 5 7/8 in.) in length in an air current of 28 m. (91.8 feet) per second, i. e. at values of R lying between 8.5×10^5 and 16.4×10^5, i. e. precisely in or close to the critical zone for this degree of similitude.

The form A of the models tested is cylindrical, truncated at the ends to a curve much like that of the forward edge of a thick wing. Obviously no direct comparison can be made between this form (especially if arranged above a false floor) and those of the classical fuselage of air craft. We may, however, take it as certain that the resistance ought only to pass through a single minimum value when the elongation is varied, i. e. the ratio of the length of the model to the diameter of the circle equivalent to its cross area. For well stream lined and isolated fuselages the best elongation, which varies slightly with R, is of the order of 3 to 5. For a straight cylinder with its generating lines at right angles to the air stream, a shape which can be made somewhat like that of the models, the optimum elongation is equal to roughly 3, and the resistance increases very quickly when this value is departed from.

According to the results given for the model A (without fixed floor nor stream lined lookout on the roof) there should be at least three minimum values of the resistance for elongations respectively less than 4, equal to 5.7, and greater than 8. The results appear most paradoxical.

d) *Numerical values of the recorded resistances.*

The recorded values of the coefficient of resistance (with the method of images B, to represent fictiously a conventional ground) are as follows :

0.345 for model B (cylinder with the generating lines transversely to the track, stream lined at the front and rear ends);

0.154 for model C (cylinder with the generating lines vertically to the track, stream lined in front and behind);

0.106 for model D (cylinder with the generating lines vertically to the track, of fish bellied section).

When the cross sections are the same, these coefficients can be compared with those of a thin disc orthogonal to the current and of a straight circular cylinder with generating lines parallel to the wind and of the same elongation as the models, obstacles for which the corresponding coefficients may be taken as 1.2

and 0.88 respectively. We get in this way the following ratios :

	Ratio of the measured resistance to that of the :	
	Orthogonal disc.	Straight cylinder.
Model B.	0.286	0.392
Model C . . .	0.128	0.175
Model D. . . .	0.089	0.12

The reduced values to which these figures are equivalent appear too favourable, especially for the models C and D, and this can be explained, as pointed out earlier, in part by the errors of the experimental layout used.

In any case for the reasons already given, these figures certainly cannot be applied to the actual vehicle under its real running conditions, even on the straight and without side wind.

The experience available in connection with fast vehicles more or less well stream lined, prevents us from hoping, as we might have from the previously quoted trials, that a railcar weighing 12 tons 13.85 m. (45 ft. 5 1/4 in.) long and of the form of model C could only require 100 H. P. for a speed of 150 km. (93 miles) an hour. It would appear prudent to increase this estimate by at least 50 %.

e) *Aerodynamical brakes with adjustable vanes.*

The arrangements experimented with, it would seem merely as a matter of interest, can certainly give a great retarding effort at high speeds, but their chief drawback is that this effect decreases *inversely as the square of the speed* as the vehicle slows down. A really useful and practical brake should be able to give as high a retarding effort as possible until the vehicle comes to rest.

To meet this condition an aerodynamical brake ought to make use of the reaction of a fluid jet or of a moving mechanism in the surrounding atmosphere. The simplest and most practical arrangement is that of an air screw driven by the motor and which, rationally, would be used normally to propel the rail motor : the screw therefore would have to be reversible.

The use of a screw of this kind has also the double advantage of *solving in the simplest way the transmission problem* for the whole range of power to be considered, and of fitting in most satisfactorily with the best aerodynamical form of the vehicle. We can consequently affirm that the torpedo shaped coach with Diesel motor and air screw deserves to be looked upon as one of the most interesting solutions of the technical problem of the rail car. In our opinion too much cannot be done to encourage designs and experiments with this system.

IV. — On a possible method of systematically testing reduced scale models.

We have already stressed the defects and shortcomings of tests carried out on reduced scale models in the air flume.

We pointed out, on the other hand, that methodical and rational experimental work was not possible with full size tests under *actual service conditions,* because the outside conditions could not be kept constant and because it is impossible to distinguish the variables from one another, the basis of « method » in the Descartes sense and as implied by all science.

We think, however, that there is a way in which more instructive tests could be carried out : this is the reproduction of the actual movement for a reduced scale vehicle in a uniform medium which can be varied as desired. By such a method varied tests could be made which could be completely analysed and which would at least supply valuable comparative data.

The method of carrying out the experiments with the various forms of vehicles working to a scale of one tenth for

example, i. e. to a larger scale than that adopted in the wind flume tests considered above, might be as follows :

The length of the actual vehicle heing 20 m. (65 ft. 7 in.) for example, its model one tenth full size (2 m. = 6 ft. 6 3/4 in.) is made to run on a circular track, also one tenth full size with all the details of the ballast and formation of a standard gauge line of say 300 m. (15 chains) radius.

Under these conditions, if the distance between bogie pivots of the actual vehicle is 15 m. (49 ft. 2 1/2 in.) it is easy to check that, in spite of the curvature of the line, the incidence of the wind on the reduced scale model running on a circular curve is practically negligible.

The line can be built of light metal of good conductivity built up of sections welded together to avoid rail joints, and its transverse cant can be made to vary with the speed so as to get the same behaviour as regards pressure on the rails as on the straight. For this purpose, the track can be carried at intervals on wide transverse sleepers, the cant of which is controlled from the centre of the circular track by pull or push rods, the thermic expansion of which conforms to that of the track. All the moving gear is fitted with rollers to reduce the stresses and driven by a servo-motor.

The above being arranged, the model can be driven by electric motors fitted to some of the axles, the supply and return of the current being through the rails suitably insulated for this purpose, especially if these and also the wheels and axles are made of aluminium or other good conducting metal.

The axles or the bogies so equipped, assembled if need be in a frame the length of which can be adjusted and carrying all the necessary recording instruments, then form a travelling laboratory with which experiments can be made with all sorts of shapes and arrangements of vehicles, and all the elements of the power absorbed for propulsion can be analysed.

The body being, in fact, carried on the frame by means of aerodynamical supports suitably located and arranged, the resistance and aerodynamical moments of the particular body can be evaluated with precision for different speeds.

By subtracting the power so consumed from that given out by the motors, the power absorbed by the running resistance and by the aerodynamical resistance of the revolving parts and by the outside projections of the body can be obtained. The analysis of the elements as of the variation of the running resistance with the speed can be calculated, for example, by altering the axle loading which only affects the mechanical resistances.

We would point out that the installation in question can be set up in a disused round house, probably to be found at some place on the railways. The first cost of the installation would be very small and the cost of making the tests extremely so. As to the results to be obtained from such a *roundabout with reduced scale models*, they ought to be as varied as fruitful.

I hope that these suggestions may receive the attention of those who occupy themselves, and rightly so, with the improvements of the efficiency of the propulsion of vehicles, and particularly of rail motor cars.

CONCLUSIONS

General remarks on the best form for railway vehicles.

We will not repeat the considerations, possibly already too-fully developed, we felt it necessary to give above on the aerodynamical problems involved in the forms of railway vehicles and on the test methods already used or on that just suggested.

There is still much to be done before

we can collect really sure experimental data on the subject as the few tests carried out only relate to a small part of the problem to be solved and only supply doubtful results or results too far from reality.

We may recall, before ending, some of the general principles which the experimental mechanics of fluids, according to the more recent results, have shown to be practically certain.

First of all, the reduction of the aerodynamical resistance is to be looked for in the suppression of all sharp corners at an angle to the local direction of the surrounding current; the surface over which the fluid flows must be *rounded off*.

Secondly, these surfaces have to be *continuous and smooth*, i. e. free from edges, projections, hollow places and openings.

Finally, the general form ought to be such as to facilitate the flow of the outside air, the shape at the rear being more elongated, fined off or tapered than at the front.

As regards the form to be given to the rail car in particular, these principles lead to the details of the vehicle being closed in as far as possible by a suitably profiled casing of as simple a shape as possible. The parts which cannot be protected in this way ought to be enclosed in their own casing suitably connected to the main casing; no rivets with visible heads, no recessed windows in the sides, no setting in of the body at the doors, and the minimum of outside fittings, each being suitably stream lined in. As a general rule drop lights ought not to be allowed, as when open they set up currents of air inside the body and seriously disturb the outside air current. All the inlet and outlet ventilation conduits or the exhaust pipes of the engine should discharge into the regular exterior current, the orifices being dimensioned and arranged so as to collect or discharge a fluid current which merges into the outside air current without disturbance.

Preferably the section in plan of the vehicle is the one to be stream lined at the front and back ends, the vertical generating lines (rectilineal or slightly curved towards the outside) having almost the same height throughout except at the front and rear where this height may be reduced progressively with advantage.

It is essential that all the lower part of the vehicle be suitably cased in. This casing can be brought down quite close to the ground; preferably no opening should be left in it with the exception if need be of that for the exhaust pipe of the engine which should obviously be at the trailing end.

It should be understood, of course, that these rules, to some extent theoretical, ought to fit in, in actual practice, with the unavoidable constructional requirements, and the purpose for which the vehicle is needed, but *too great care cannot be given to the exterior details of the outside of the bodies when looking for the best solution.*

It can be stated without exaggeration that the advantage of certain pretended « aerodynamical » shapes, on account of their general lines inspired by the above principles, is totally destroyed in actual work by the sharp edges, projections, hollows, and various additions even of small dimensions in practice added during the actual construction of the vehicle, if these details are not given the attention they should have.

[621 .132.8 (.485)]

A new non-condensing turbine locomotive.

(*The Railway Gazette.*)

By the courtesy of the Ljungström Steam Turbine Company (Aktiebolaget Ljungströms Angturbin) of Stockholm, we are enabled to illustrate and describe herewith a new non-condensing steam turbine locomotive constructed by them and which has been undergoing a series of comparative tests on the Grängesberg-Oxelösund Railway. The locomotive is of the 2-8-0 type with a short four-wheeled vestibuled tender. In spite of the many advantages of the condensing turbine-driven locomotive, the manufacturing cost and rather complicated arrangement prevented a general adoption of condensing-turbine drive. The experience with these locomotives, however, proved that the Ljungström locomotive turbine is a satisfactory prime mover for locomotives. The company, therefore, constructed the non-condensing turbine locomotive.

The somewhat complicated construction of the condensing type has been avoided in this locomotive. The turbine is located in front of the smokebox, as shown in the drawing, and is connected to the side rods through a gear and jackshaft arrangement. The tests made showed that the quantity of steam used amounted to 17 600 lb. an hour with steam at a temperature of 752° F. The boiler pressure maintained during the run was 184.5 lb. Steam entered the turbine at 163.2 lb. and was exhausted at 3.55 lb. The gear transmission is similar in design to that applied to the condensing turbine locomotive built for the Swedish State Railways. This drive is constructed with a triple gear and with a movable coupling shaft which also serves as a driving shaft. Reversing is accomplished by disengaging two gears and bringing an immediate gear into mesh. The

Fig. 1.

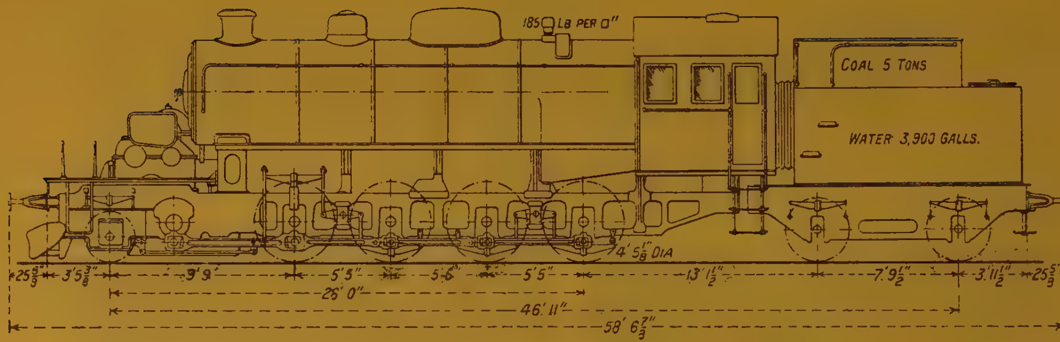


Fig. 2. — Diagram of the new 2-8-0 t pe Ljungström non-condensing locomotive.

reversing operation is accomplished as on piston-type locomotive équipped with a screw-and-crank reverse gear. Apart from the turbine and gear, and jack shaft connections to the side rods, the construction of the locomotive is essentially similar to that of a reciprocating locomotive.

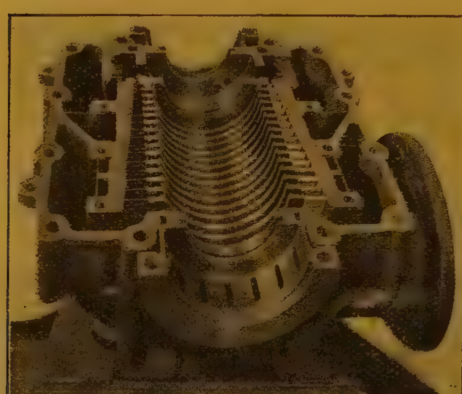


Fig. 3. — Lower half of turbine casing.

Air for combustion is admitted below the grate through dampers in the ash-pan. Because of the steady flow of steam from the turbine through the exhaust nozzle, a perfectly even draught is secured. For this reason the locomotive can operate with a lower back pressure. The exhaust nozzle is designed so that when the quantity of steam through the turbine is small, the nozzle adjusts automatically to produce a proportionally greater draught. Steam is passed from the boiler through a regulator valve in the dome, thence through the superheater, steam chest and steam strainer to the admission valve, which is bolted to the turbine casing. The admission valve is provided with five nozzles which are operated from the cab. The regulator is used only as a main stop valve for the boiler and is opened wide at the start and closed at the end of the run.

Test conditions and results.

A large number of tests have been made with the locomotive, on some of which a dynamometer car was used. On one run a train of 1 831 tons was hauled up a 1 in 100 grade. The dynamometer recorded a drawbar pull of 49 000 lb. A comparison of this performance with reciprocating locomotives of the same adhesive weight and pulling a train up the same grade showed that the maximum drawbar pull obtained was 37 500 lb. Comparative tests with a three-cylinder single-expansion locomotive showed an average fuel saving of approximately 10 % per drawbar horsepower-hour. This economy in favour of

the turbine locomotive is remarkable considering the fact that the turbine is only of 1 200 H. P. normal rating.

The boiler efficiency of the turbine locomotive, however, was found to be less than the boiler efficiency of the piston type locomotive and actual fuel savings could not be definitely ascertained during these tests. Alterations are now being made to the boiler and a considerably higher fuel economy is expected in future comparative tests with piston-type locomotives having boilers of the same efficiency. The builders anticipate that, owing to the efficiency of a steam turbine increasing with the capacity, the

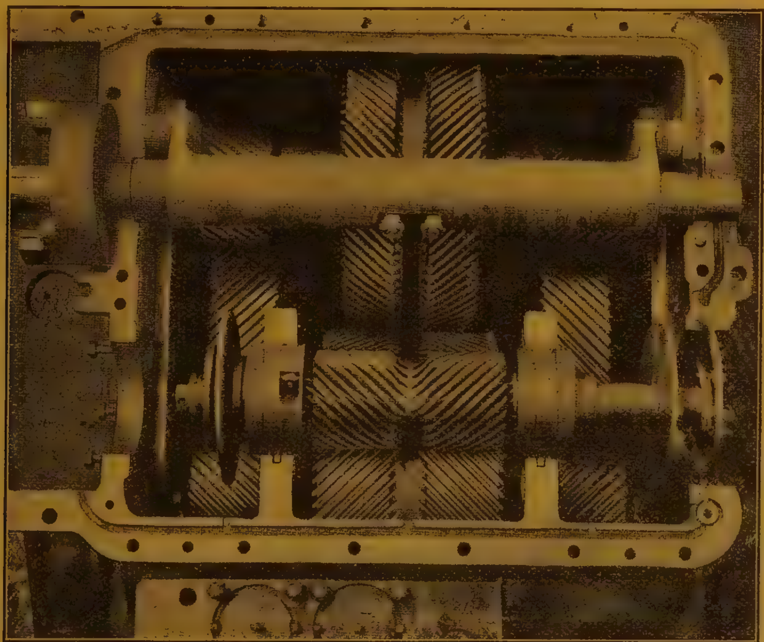


Fig. 4. — Transmission gears with casing cover removed.
The reversing gears are on the right.

fuel saving will be approximately 30 % for a 4 300-H. P. locomotive. As a result of the higher efficiency and even torque, the gross tonnage of trains can be increased 25 % and because of the smooth running qualities of the locomotive the load on the coupled wheels can be increased from 10 to 15 % as compared with three-cylinder locomotives and from 20 to 25 % as compared with two and four-cylinder locomotives.

The leading particulars of the locomotive are :

Turbine steam pressure at intake . .	163.5 lb.
Turbine steam pressure at exhaust. .	4.4 lb.
Turbine steam temperature	752° F.
Boiler :	
Type	Straight top.
Steam pressure	185 lb.
Grate area	32.3 sq. ft.

Heating surface :	
Evaporative	1 616 sq. ft.
Superheating	1 076 sq. ft.
Combined.	2 692 sq. ft.
Wheelbase :	
Rigid	16 ft. 3 in.
Total engine and tender.	46 ft. 11 in.
Weight in working order on coupled wheels	70 tons 17 cwt. 2 qr.
Total	115 tons 12 cwt. 1 qr.
Tender :	
Coal capacity	5.5 tons.
Water capacity.	3 900 gallons.

It is reported that the non-condensing turbine locomotive has proved its reliability in service and that there has been a considerable reduction in maintenance costs. This is attributed primarily to the closed lubrication system and absence of rubbing surfaces, such as those of the customary cylinder, piston and cross-head arrangement. By conversion of a reciprocating locomotive designed for a speed of from 40 to 60 m. p. h. to condensing turbine locomotive drive it is expected that the speed can be increased from 27 to 36 %.

The locomotive, which was built at the works of Nydquist & Holm, develops a tractive force of 47 000 lb. and is designed for a maximum speed of 43.5 m. p. h.

[621. 33 (.439)]

Electrification of a section of the Budapest to Vienna line of the Hungarian State Railways.

Traction using alternating current on the Kandò system.

(From *Le Génie Civil.*)

As from September 1932, a section of about 100 km. (62 miles) long, Budapest to Komarom (fig. 1) on the Vienna line, has been electrified by the Hungarian State Railways and is to be extended to Hegyeshalom on the Austro-Hungarian frontier [about 190 km. (118 miles)]. This electrification deserves attention because it uses a particular system of traction invented by Mr. Kandò, Engineer, in which the high-tension single-phase current instead of being simply tranformed on the locomotive into low-tension current driving induction motors, as on the Swiss Federal Railways for example, is modified by a « phase converter », which we will consider later on, and fed to a single and very powerful traction motor as multi-phase current.

The Hungarian Railways were led to consider the electrification of part of their lines as a means whereby to save the good quality coal which the Hungarian mines cannot produce in large enough quantity to meet both domestic and railway requirements. Current for electric traction can be obtained from power stations using coal of very poor quality, in specially designed boilers, which coal is quite unsuitable for locomotive purposes.

It was recognised, however, that power stations supplying the State Railways alone would not give good financial results, and that the current required for electric traction would have to be taken from a general distribution system supplying the whole country, so that only a few very large power stations equipped with large generating sets would be necessary.

In accordance with this general programme, the Hungarian Transdanubian Electricity Company has built the Banhida power station (fig. 1), about 75 km. (47 miles) west of Budapest, on the Vienna line.

This station situated on the edge of the Tata coal field burns coal of no saleable value, not previously mined, and supplies energy to Budapest and its sur-

Fig. 1: — Map of the line from Budapest to Vienna, showing the electrified section to Komaron. The electrification will be extended to Hegyeshalom.

rounding districts, as well as to the electrified line which we are considering, by a 110 000-volt transmission line closely following the railway. It is continued towards Györ in the Hegyeshalom direction. The traction line is fed at 16 000 volts by four substations only, equipped with 110/16-kilovolt static transformers.

Alternating current locomotive, Kandò system.

As is known, the systems of electric traction for main line work proved by practice are: direct current adopted by the French railways; three-phase by the Italian State Railways; and the single-phase adopted by the Swiss and Austrian railways as well as by other countries such as in Scandinavia.

We will not compare the different systems again, as this has been done already in the *Génie Civil* (1). Each system has its partisans. We would point out however that the three-phase system, in spite of its great advantages from the locomotive point of view, is most inconvenient in practice as two overhead wires have to be used for each line, and these have to be perfectly insulated from one another (which is difficult to arrange in stations where the lines cross one another and where there are many sidings); it is actually only used in Italy (2) and there is little likelihood of its use being extended.

The Hungarian engineer, Mr. Kandò, who died in 1931, developed a system by which it is possible to use single-phase current at the industrial frequency of 50 cycles (instead of the 16 2/3-cycle frequency, as in Switzerland) (1) supplied by any power station, and also usable for other purposes, while the motor or motors are able to take advantage of the multiphase current as the result of the conversion by a special machine known as the « phase converter ».

This rotary machine interposed on the locomotive between the current collectors and the traction motor or motors, consists of a stator carrying in separate slots:

1. a high-tension single-phase winding fed directly from the contact line;

2. a low-tension multi-phase winding feeding the traction motor or motors.

The rotor has an exciter winding which can be regulated.

Mr. Kandò, in accordance with an arrangement made with the Hungarian State Railways, built an experimental locomotive which was tested as far back as 1923 on a 15-km. (9.3 miles) section of line between Budapest (Western station) and Alag, which section was electrified for this puspose (fig. 1). This locomotive was subsequently rebuilt in accordance with the results of the first tests and again tried out up to 1931, working both goods and express trains. It was the prototype of the locomotives

(1) Cf. in particular the *Génie Civil* of the 23 April 1921, page 350, and 17 December 1927, page 621.

(2) This application, an old one, is limited to the lines in the Genoa and Turin districts; direct current is likely to be adopted for future electrifications.

(1) As early as 1905, one of the Swiss lines was equipped by the Oerlikon Company for single-phase current at 15 000 volts, 15 cycles. Towards 1910 the « Compagnie du Chemin de fer des Alpes bernoises » (Loetschberg Line) adopted the same characteristics, as reported in the *Génie Civil* of the 18 February 1911. A little later, the Federal Railways set up a Commission to investigate the whole of the traction systems then in use, and decided to use the same system as that of the Loetschberg Line. In practice the frequency of $16\ 2/3 = \frac{50}{3}$ was adopted instead of 15.

built for the regular working of the Budapest to Hegyeshalom line. These engines are of two types, one for express trains and the other for goods (fig. 6), and as a beginning two units of each type were built.

The general layout of the two types is identical; the only difference is in the wheel arrangement, the passenger engines being of the 1-D-1 (2-8-2) type and the goods of the 0-F-0 (0-12-0) type. The leading dimensions are as follows :

		2-8-2 *type.*	0-12-0 *type.*
Overall length		13.70 m. *(44 ft. 11 in.).*	13.95 m. *(45 ft. 9 in.).*
Diameter of driving wheels		1.66 m. *(5 ft. 5 3/8 in.).*	1.15 m. *(3 ft. 9 9/32 in.).*
Diameter of carrying wheels		1.04 m. *(3 ft. 5 in.).*	»
Weight in working order		94 t. *(92.5 Engl. tons).*	94 t. *(92.5 Engl. tons).*
Adhesive weight		66.2 t. *(65 Engl. tons).*	94 t. *(92.5 Engl. tons).*
Maximum axle load		17.8 t. *(17.5 Engl. tons).*	17.8 t. *(17.5 Engl. tons).*
Power of motor — continuous rating.		2 200 H. P.	2 200 H. P.
Maximum power		3 500 H. P.	3 500 H. P.
Hourly speed steps	1	24.2 km. *(15 miles).*	16.6 km. *(10.3 miles).*
	2	50 km. *(31 miles).*	34.3 km. *(21.3 miles).*
	3	75 km. *(46.6 miles).*	51.5 km. *(32.0 miles).*
	4	100 km. *(62 miles).*	68.3 km. *(42.4 miles).*
Corresponding tractive effort at the drawbar.	1	8 977 kgr. *(19 790 lb.)*	13 150 kgr. *(28 990 lb.).*
	2	9 880 kgr. *(21 780 lb.).*	14 450 kgr. *(31 860 lb.).*
	3	6 926 kgr. *(15 270 lb.).*	10 560 kgr. *(23 280 lb.).*
	4	4 785 kgr. *(10 550 lb.).*	7 600 kgr. *(16 755 lb.).*

Figure 2 is an elevation of the passenger engine. The 16 000-volt 50-cycle single-phase current is picked up by the pantographs (*a*) and fed to the phase convertor (*c*) through the oil circuit-breaker (*b*) carried on the roof. The phase convertor forms a self-contained unit with the exciter (*d*), the starting motor, the cooling water circulating pump (*q*) and the oil and water coolers (*e*). At the middle of the frame is placed the traction motor (*f*), the number of poles of which is variable according to which of the four running speeds is selected; the motor is fed by the phase converter with multi-phase current. The number of poles is changed by means of a pole reverser (*i*), fig. 3, by which the terminals of the secondary winding of the phase converter can be connected with the different slip rings of the traction motor while the multiphase winding of the stator is connected to the liquid starter (*h*) placed beside the motor on the frame of the locomotive. Above the main motor is placed its cooling fan (*g*) driven by an auxiliary motor. Two cranks are keyed on the ends of the main motor shaft, at 90° one to the other, and drive the 4 driving axles through the rods (*o*) (fig. 2), the triangle frame (*v*) and the jack shaft (*p*) which also has cranks set at an angle to one another. The compressors (*m*) are placed close to the liquid starter.

At each end of the frame there is a driver's compartment (*l*) with the master controller (*t*) (fig. 2) and the necessary meters. These two compartments with their main equipment are illustrated in figure 4 and are connected together by corridors arranged on both sides of the electrical equipment.

We will only give here a few general notes on the principal parts of the elec-

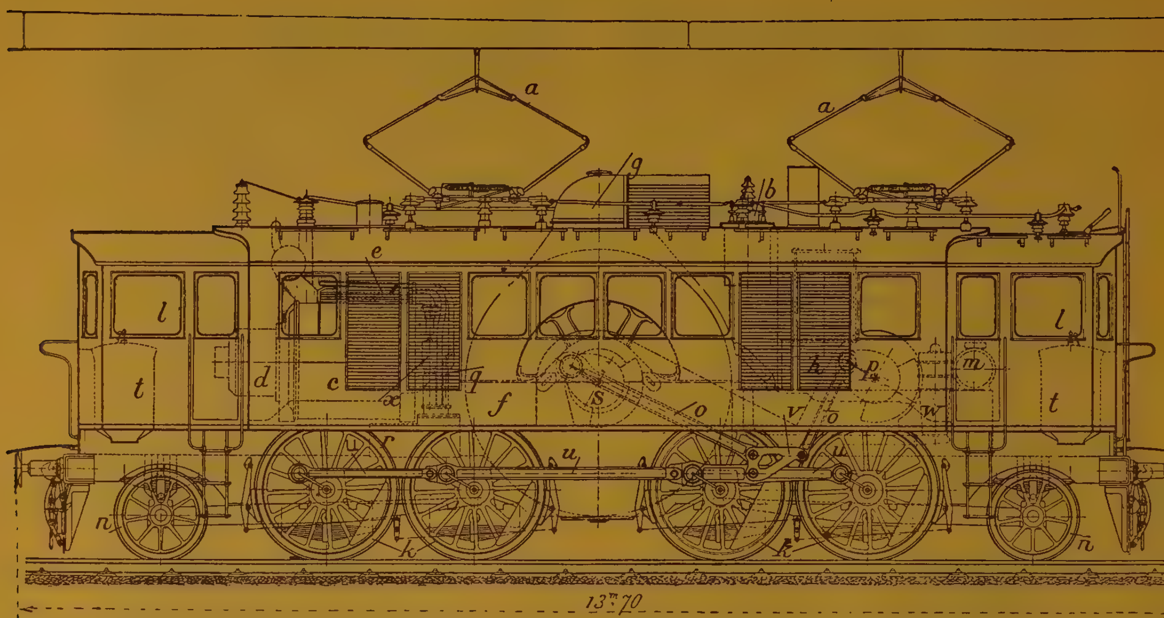


Fig. 2. — Elevation of the electric locomotive with the Kandó phase converter (passenger type).

a, current collectors;
b, main circuit breaker;
c, phase converter;
d, exciter;
e, coolers;
f, traction motor;
g, fan;
h, liquid starter;
k, driving wheels;
l, driving compartments;
m, compressors;
n, carrying wheels;
o, connecting rods;
p, jack shafts;
q, water circulating pump;
r, cooling water tank;
s, cranks;
t, master controllers;
u, coupling rods;
v, triangular coupling;
w, pumps of the liquid starter;
x, auxiliary cooling water pump.

trical gear, as any further details can be obtained from a booklet published in English by the Hungarian Railways on the electrification of the Budapest to Hegyeshalom line.

Phase converter. — The phase converter (fig. 5), the essential feature of the Kandò system, converts, as we have already said, the single-phase current picked up from the contact line into multi-phase current fed to the traction motor.

This converter is a four-pole synchronous machine provided with a number of windings, the rotor being excited by continuous current supplied by a dynamo carried on the same shaft. This rotor revolves at the rate of 1 500 r. p. m.

The casing of the stator is mainly composed of segment-shaped sheet iron punchings in which the slots carry four windings :

1. The primary single-phase four-pole high-tension winding in the 48 slots furthest from the air gap. The winding is connected at one end to the 16 000-volt trolley through the oil circuit breaker and the pantographs, and is earthed at the other;

2. Auxiliary single-phase winding, in the same slots, connected to the former

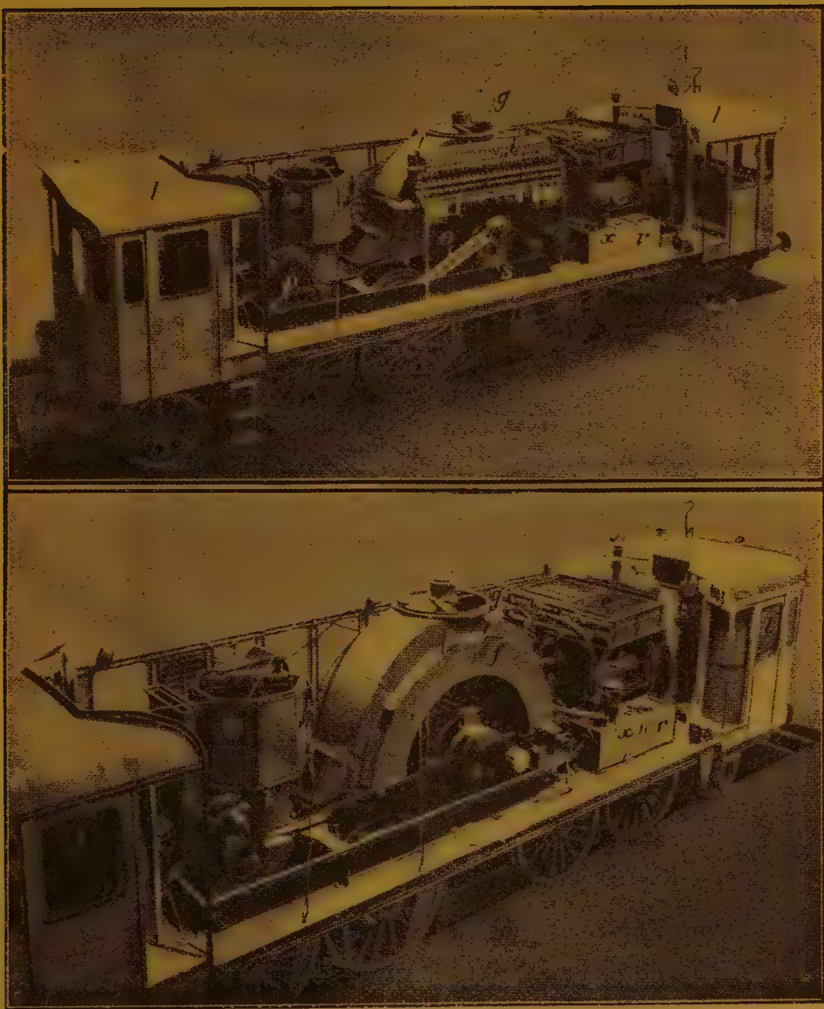


Fig. 3. — General view of the two sides of the passenger locomotive, taken during erection.

c, phase converter;
e, converter oil and water coolers;
f, traction motor;
g, traction motor fan;
h, liquid starter;
i, pole reverser;
l, driving compartments;
o, connecting rod;
p, jack shaft;
r, converter cooling water tank;
s, driving cranks;
x, auxiliary pump for the converter cooling water.

and giving a voltage of 820; it is intended for feeding one phase of the starting motor, the lighting transformer and the transformers of the different meters;

3. The secondary multi-phase winding carried in the 72 slots nearest the air gap and feeding the traction motor. This is a closed loop winding and can

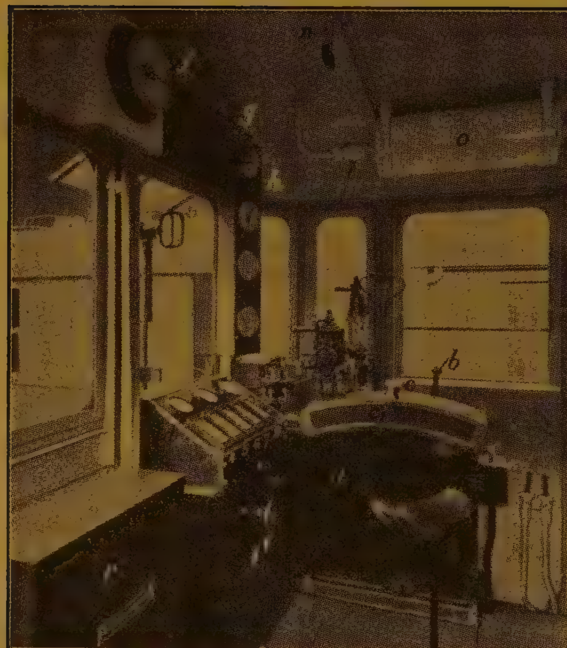


Fig. 4. — View of one of the driving compartments.

a, master controller;
b, starting lever;
c, speed lever;
d, instrument table;
e, wheel for regulating the excitation;
f, primary power factor indicator;
g, indicator lamps;
h, pressure gauge;
n, hand tripping device of the oil circuit breaker;
o, air reservoir for the whistle;
r, automatic air pressure regulator.

supply either two-, three- or six-phase current. The voltage over terminals varies between 850 and 1 300 volts according to the load and the excitation;

4. A three-phase winding lodged with part of the preceding winding in 16 slots between the two preceding groups of slots and supplying 70- to 110-volt current for the auxiliary motors.

The primary winding being connected to the high-tension of the trolley wire, the insulation has to be particularly efficient, and it is ensured, at the same time as the cooling, by immersing the iron core of the stator and its windings in an oil bath. This oil is pumped into a cooler carried above the oil-tight sealed casing of the stator from which it flows back into the casing.

The air gap of the phase converter is 21 mm. (53/64 inch), part being occupied by the copper damper system surrounding the rotor, and part by a bakelite-paper tube.

The rotor has 32 slots in which are carried the coils of the four-pole exciter winding; one end of this winding is earthed. The phase converter having in addition to compensate the whole reactive current of the traction motor, considerable at heavy loads, the rotor

has to dissipate considerable quantities of heat, as a rule 15 to 20 calories (59 to 80 B. T. U.) per second and possibly even 35 or 40 calories (139 or 159 B. T. U.).

For this reason it is water cooled; 36 copper cooling tubes are placed in the longitudinal slots in the rotor and the water is driven through them by two centrifugal pumps; the water circulates through the rotor and then passes through an air cooled radiator to be recooled, a powerful current of air being driven through the radiator by a fan. This radiator works in common with the stator oil cooler.

Centrifugal release. — As with the Kandò system braking by regeneration on down gradients and when stopping

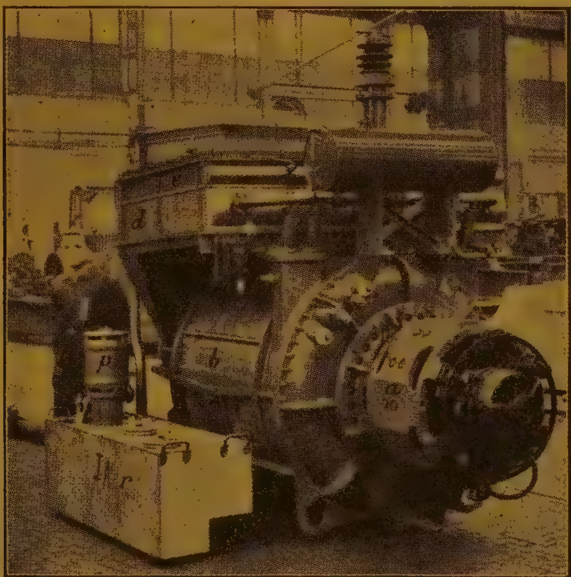


Fig. 5. — View of the phase converter, from the exciter side.

a, exciter;
b, casing of the phase converter forming the oil tank;
d, oil cooler;
e, water cooler;
p, cooling water pump.
r, water tank.

is possible, the main circuit breaker might cut out when working in this way and the phase converter would not be kept in synchronism with the frequency of the power station, in which event the rotor would race; to prevent this from occurring, a centrifugal release reduces at the same time the excitation of the exciter and cuts out the traction motor from the phase converter.

Starting motor. — The high tension primary winding of the phase converter, even if the latter be stationary, can always be put into circuit without any fear of excessive current strength; this putting in circuit however is not sufficient to start the rotor of the converter. For this to occur the auxiliary starting motor fitted on the converter on the exciter side has to be brought

into action. This motor is a two-phase induction motor with the rotor short circuited, keyed on the rotor shaft of the converter; its stator fastened to a bearing of the converter has two windings connected respectively to the high tension winding and to the auxiliary single phase winding of the converter stator.

This starting motor runs up the speed of the phase converter to 1 500 r. p. m. in a few minutes; it is protected by a cut out.

Figure 5 shows the compact arrangement of the phase converter which, with its auxiliary devices, exciter, starting motor, centrifugal release, oil and water pumps, radiators, weighs 12.7 tons without water and oil.

Traction motor. — The traction motor is a multi-phase induction motor with the primary winding carried in the rotor and the secondary winding in the stator. It has, as shown above in the table of characteristics of the locomotive, four speeds, the change being made by altering the number of poles of the rotor.

The 540 slots of this rotor carry two independent windings, the first, the outer, is a three-phase winding with 72 poles, which can be altered to 36 poles; it is connected to six rings. The second, the inner, is a six-phase winding with 24 poles which can be reduced to 18, and is connected to ten slip rings. All these rings are insulated and are fastened to the rotor centre. As each winding can be connected to two different numbers of poles four combinations can be obtained. Consequently when the inner winding fed with two-phase current is connected to 18 poles the speed of the motor is 333 r. p. m., corresponding to a locomotive speed of 100 km. (62 miles) an hour. If the same winding is connected to 24 poles and fed with six-phase current, the speed of the motor falls to 250 r. p. m., and that of the locomotive to 75 km. (46.6 miles) an hour. If the outer winding is brought into circuit, according as it is connected to 36 or to 72 poles, the speed of the motor is 167 or 83 r. p. m., and that of the locomotive 50 or 25 km. (31 or 15.5 miles) an hour. The above figures apply to the passenger locomotive which is of the 2-8-2 type; in the case of the goods locomotive of the 0-12-0 type the wheels being smaller, the four speeds lie between 68 and 16 km. (42 and 10 miles) an hour.

The secondary winding of the traction motor carried on the 576 slots of the stator, is a looped multi-phase winding, it being possible to short circuit the 48 sections in series independently one of the other; they are permanently connected to the 48 electrodes of the liquid starter which will be dealt with later.

The rotor shaft is carried by bearings, the brasses of which can be adjusted in two directions so as to be able to set the air gap between the rotor and stator very accurately.

The traction motor is cooled by air circulation provided by a fan fitted above the motor as seen in figures 2 and 3. The motor has an outside diameter of about 3.25 m. (10 ft. 8 in.) and weighs 18.5 t. (18.2 Engl. tons) including two cranks and their balance weights. The large dimensions of this motor have made the parts easily accessible.

Switch gear. — The first function of the switch gear is to make it possible, independently of the skill of the driver, to start the locomotive and vary its speed continuously. This is ensured by a « pole reverser » which makes the desired connections of the traction motor and by an automatic regulation of the oil starter connected to the secondary circuit of the motor during the acceleration period and short circuited when the normal speed is reached.

The second function of the switch gear consists in regulating the excitation of the phase converter for a given speed

Fig. 6. — View of a goods locomotive.

of the locomotive, according to the load at each instant, so that the load factor of the phase converter may be maintained at unity and that the traction motor may always work at the highest efficiency.

For these two functions of which we have just spoken to be covered, the pole reverser, the liquid starter, and the phase converter's excitation rheostat have to be operated and regulated automatically. This is done by the two « master controllers » in the driving compartment. The method of operation is simple : two levers, one to regulate the speed and the other the tractive effort, while starting and changing speed, have to be moved; the regulation of the secondary voltage while running is automatic, and the driver has no need to take any action.

In the publication issued by the Hungarian State Railways and mentioned above, a complete description is given of the pole changer, the liquid starter and a master controller, as well as of the method of operation of this equipment as a whole, in too great detail for it to be covered in the scope of this article.

Each control compartment (fig. 4) has the necessary instruments, such as the voltmeters, showing the line voltage, the voltage of the excitation circuit, a wattmeter showing the power absorbed by the phase converter, a power factor indicator, a speed indicator for the converter, thermometers, signal lamps, etc... The switches are push button controlled, as are the brakes, sanders and whistle.

The compressed air for the brake and the accessories is supplied by two reciprocating compressors of different designs. 80 % of the adhesive weight can be braked.

Frame and wheels. — There is nothing particular about the frame, the sole bars of which are 12.50 m. (41 feet) long. In the two 2-8-2 locomotives the trucks are of different patterns which results in slight differences in their arrangement and in the axle side play.

The driving gear (fig. 7) is arranged in the following way, taking into account the fact that the driving axles, thanks to the springs, must rise or fall a certain amount relatively to the underframe, i.e. relatively to the shaft of the traction motor and the jack shaft, the relative positions of which are fixed.

The driving mechanism first of all consists of the rods AC and BD connected to the motor and to the jack shaft crank pins respectively; then a triangular frame with three pivots C, D, E coupling these driving rods to the coupling rod LM. If AC and BD be continued, they intersect in each position at a point F lying on LM. The kinematical study of this gear as a whole during the rotation of the traction motor shows that the mechanism can move freely in the vertical direction, whereas it is rigid in the horizontal, and consequently transmits the forces to the coupling rods GH, IK, LM connected by the short rods HI and KL. So that the coupled wheels may move laterally within

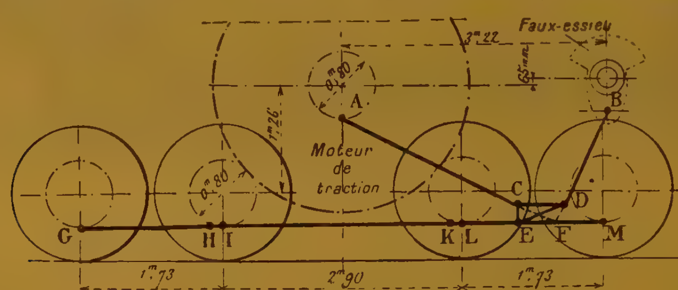


Fig. 7. — Driving gear.

Note : Faux-essieu = Jack shaft. — Moteur de traction = Traction motor.

the limits allowed, the ends of the rods have spherical bushes.

* * *

The Hungarian State locomotives were built jointly by the Ganz Co., of Budapest, the Locomotive Workshops of the Hungarian State Railways, and the Metropolitan Vickers Electrical Co., Manchester. The brief description given above shows that the Kandò system invites attention by its original features. The ability of the inventor has been recognised by electrical engineers in different countries. As an example, Mr. Hug, a Swiss engineer, gave a paper before the French Society of Electrical Engineers on the 5 December 1931, on the electrification of the Budapest-Hegyeshalom line, then in hand, and described the first locomotive used for several years during the trials on the Budapest to Alag line.

Mr. Gratzmuller, at the end of the paper, made certain remarks, among others the following : « What has interested me most has been the part played by the late regretted Mr. Kandò. He took up courageously the use of electric power collected in the form of single-phase current at industrial frequency from a single contact line and converted it on the locomotive into three-phase current feeding the motors. In this way the work done in the past to develop the three-phase locomotives will not be lost. »

The opening of the Budapest to Komarom section to service prior to its extension to the Austro-Hungarian frontier successfully crowns the perseverance of this eminent engineer.

J. L.

[621. 43]

Gebus automatic control system,

by EDWIN P. A. HEINTZE.

(*The Railway Gazette.*)

An interesting and as yet little known control system has been adopted on the new high-speed Diesel-electric railcar which has been commissioned by the German State Railway Company for express passenger service between Berlin and Hamburg. This car, familiarly known as the *Flying Hamburger,* has already been described (1), so it will suffice to say that it consists of two symmetrical coupled bodies supported at their ends on bogies having a wheelbase of 137 inches. The coupled ends of the bodies rest on a common bogie of the same size, carrying two series-wound motors of 230 kw. constant ouput at 2 060 r. p. m. These drive the wheels through spur reduction gears having a ratio of 2.61 to 1.

The dual car, which has an overall length of 137 feet and the bodies of which are joined by bellows, is equipped with two Maybach 12-cylinder high-speed Diesel engines, each having a constant output of 400 B. H. P. at 1 400 r.p.m. and an overload capacity of 420 B. H. P. One engine is mounted in each end bogie and is flexibly coupled to a shunt-wound dynamo of 270 kw. constant capacity at 1 400 r. p. m. The full load fuel consumption of these engines is about 0.30 B. H. P. per hour, and about 0.44 lb. per B. H. P. per hour at light load.

When considering the type of speed control to adopt, the German State Railway Company decided to make a test with the Gebus system, which has proved highly successful on the Czechoslovakian railways, where 43 railcars and five shunting locomotives are fitted with it. This system is the invention of an Austrian engineer named Morzik Gelinek, and is marketed by the firm of M. Gelinek & O. Judtmann, of Vienna-VIII, Langegasse 5, which also possesses the British patent No. 295 777 covering this invention. A car or train equipped with the Gebus control system is controlled solely by one lever, which regulates the amount of fuel injected into the cylinders of the engines coupled to self-exciting shunt-wound dynamos. As is well known, the pressure of the current supplied by such generators varies proportionately to the engine speed. At very low engine speed, the dynamos are not excited, so only a very weak current, due to residual magnetism, flows to the motors. As the engine speed is gradually raised, the dynamo voltage builds up and an increasingly strong current is transmitted to the motors, which gradually commence working so that the vehicle is brought into motion without jerk. Further movement of the fuel control lever increases acceleration until a point is reached when the speed of the vehicle corresponds with the tractive force and a state of balance is established, and no further increase of speed takes place. During operation the current consumption of the motors varies according to the varying track resistance due to gradients. To obtain a constant load on the engine it is therefore necessary that the voltage of the current supplied by the dynamo should vary in inverse propor-

(1) See *Bulletin of the Railway Congress,* July 1932, pp. 1431 to 1433.

tion to the strength of the current, that is, means should be found to keep the product of current intensity and voltage constant, which implies constant engine load. This is achieved by the Gebus control system, which gives, at constant engine speed, approximately constant performance, and at varying speeds proportionate outputs so that, in effect, it operates at practically constant torque.

The Gebus system ensures an automatic regulation independent of current strength and torque by employing what may be regarded as oversize dynamos — shunt-wound or separately-excited — working normally on the border of excitation. In other words, the dynamo operates with low magnetic saturation on

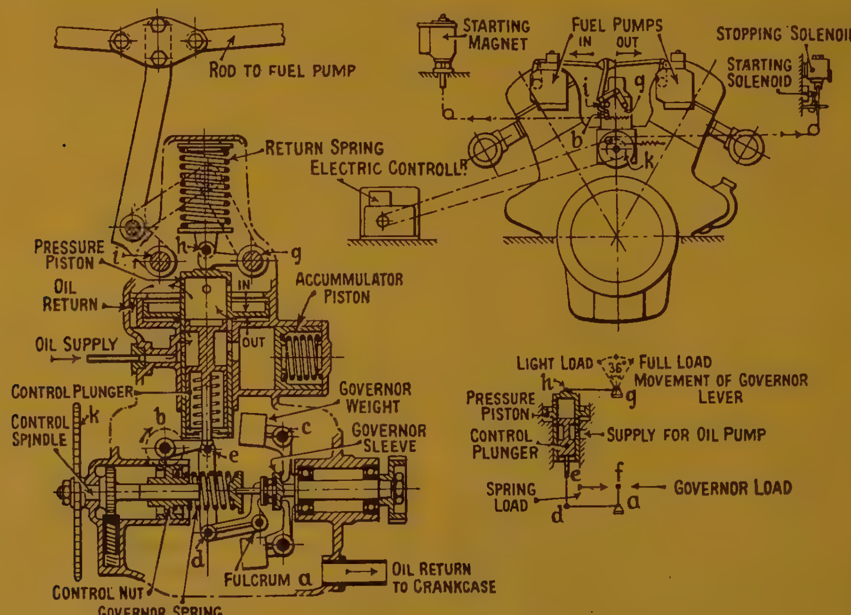


Fig. 1. — Control arrangement of the German high-speed Diesel-electric railcar.
(The reference letters connect the three diagrams.)

the lower straight section of its voltage characteristic curve, thereby attaining a practically constant performance due to the voltage rising and falling in inverse proportion to the varying strength of the current taken by the motors. It is possible so to balance the characteristics of such a dynamo by using a relatively large air gap and a lightly potentiating compound winding that it will give an approximately constant output despite varying current consumption; thus the product of current intensity and voltage is maintained constant, a characteristic of the Gebus system which simplifies the control arrangements of a railcar.

With this control system it is necessary to use a relatively large dynamo — in fact the larger the dynamo the better. This disadvantage, however, is offset by the simplicity of the system. The Gebus control arrangements also ensure automatic performance control in the event of the engine failing to develop its full power owing to any defect or to inten-

tional throttling. The output is then still more or less maintained with the dynamo working at a speed just above that at which self-excitation commences. For this reason the driver is able to regulate the power required according to the number of trailers and the load carried and the exigencies imposed by the time table by merely setting the throttle lever. Reduced power requirements, therefore, also mean reduced engine speed and wear. Furthermore, by altering the exciter resistance or changing over the excitation coils, it is possible to reduce the requisite speed for maintaining excitation whenever lower performance is required.

The entire electrical equipment on the new high-speed Diesel-electric railcar has been supplied by Siemens-Schuckert, of Berlin-Siemensstadt. As two Diesel engines at opposite ends of the car have to be kept in synchronous operation, electrical fuel feed control had to be adopted. This consists of two small electric motors, one for each engine, which directly influence the governors controlling fuel injection. The driver merely has to manipulate the controller through which these two motors are jointly regulated. Depending on the direction of rotation of these motors, the governors on the engines are adjusted so as to increase or reduce the quantity of fuel injected.

Current for lighting is supplied by two dynamos under the floor of the cars, these being driven by long-jointed shafts coupled to the main dynamos in the end bogies of the car. The two propeller-shafts pass through box-like chambers under the cars containing radiators for the engine cooling water. A cooling draught is produced by fans fitted on the shafts, where they pass through these chambers. The dynamos also charge accumulators which supply current for starting the Diesel engines by means of the dynamos in the usual way.

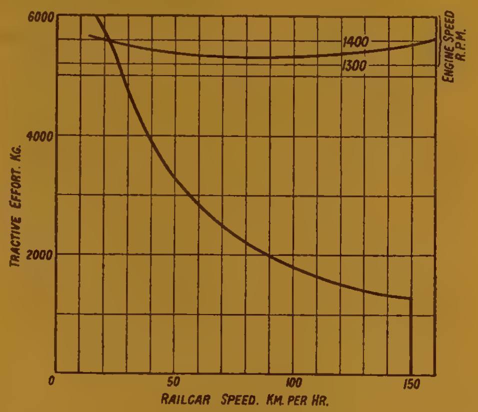


Fig. 2. — Performance curves for the railcar with both 410-B. H. P. engines in operation.

The accompanying diagram displays the tractive effort of the car, with its two engines operating, in relation to engine speed and car speed, and shows how, virtually, at all speeds the engine operates under constant full load. Reduction in car speed, arising from increased track resistance, is fully provided for by the control system used, resulting in automatic increase of tractive effort owing to the automatic balancing of current strength and pressure.

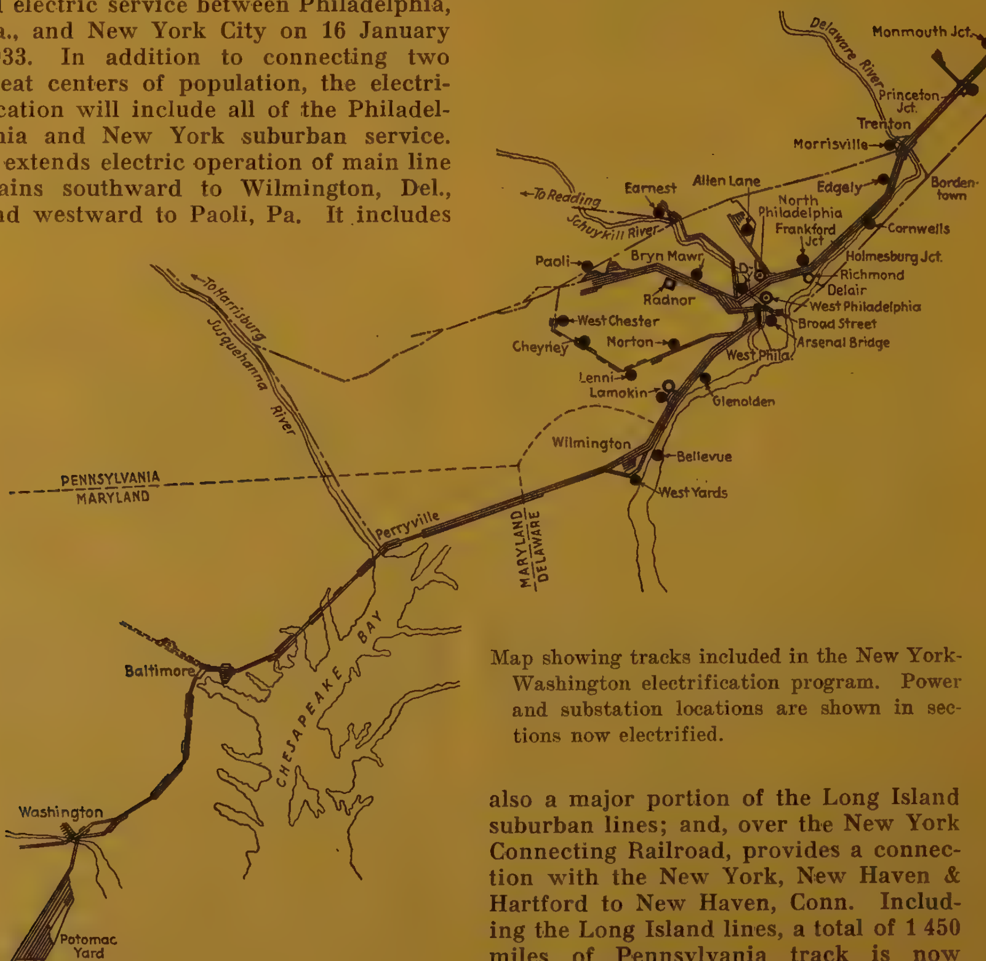
[621. 33 (73)]

The Pennsylvania Railroad electrification.

(From *The Railway Age.*)

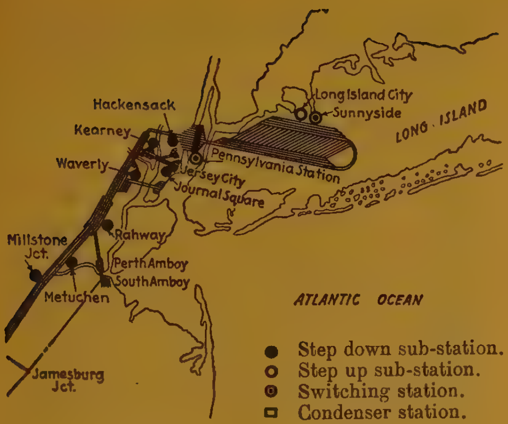
I. — The Philadelphia-New York line and the Philadelphia-Washington project.

The Pennsylvania Railroad inaugurated electric service between Philadelphia, Pa., and New York City on 16 January 1933. In addition to connecting two great centers of population, the electrification will include all of the Philadelphia and New York suburban service. It extends electric operation of main line trains southward to Wilmington, Del., and westward to Paoli, Pa. It includes



Map showing tracks included in the New York-Washington electrification program. Power and substation locations are shown in sections now electrified.

also a major portion of the Long Island suburban lines; and, over the New York Connecting Railroad, provides a connection with the New York, New Haven & Hartford to New Haven, Conn. Including the Long Island lines, a total of 1 450 miles of Pennsylvania track is now



under electric operation. Passenger trains on the New York-Philadelphia-Wilmington-Paoli lines are now operated electrically.

The electrification program now authorized also includes the line from Wilmington, south to Washington, D. C. The New York - Washington line is 230 miles in length; it consists of stretches of two, four and six tracks, and serves New York, N. Y., Philadelphia, Pa., Baltimore, Md., and Washington, D. C., as well as many other large and important cities and towns lying between them. It is anticipated that over this piece of railroad there will be a daily electrified train movement in normal times of 60 freight trains and 830 passenger trains, included in which will be 492 multiple-unit trains. This movement represents a freight trailing gross ton-mileage of 10 030 000 000, a passenger car-mileage of 133 575 000, and an electric locomotive mileage of 17 787 000. In addition to this movement, there will be a daily movement of 130 interdivisional freight trains over some portions of the electrified zone, which movement will be electrified as the electrification is extended westward.

A number of non-electrified lines and sidings connect with the electrified territory. The yard freight switching and pick-up movement required to serve these lines and sidings will not at the present time be electrified.

Engineering developments.

Great courage and long and careful planning have been required to develop a co-ordinated plan and new types of equipment capable of meeting the unusual demands imposed by the service requirements of this busy section of railroad. Years ago the Pennsylvania engineers came to the conclusion that the greatest possibilities for an electrification of this kind lay in the single-phase alternating-current system. At that time there were no motors capable of meeting the requirements of today, but the Pennsylvania management induced the large electrical manufacturers to combine their best engineering talent, with the result that a locomotive motor was produced which develops 625 H. P. continuously at the driver rims, over a wide range of speed. At the higher speeds the power is sustained to a degree which has heretofore been impossible in any previous type of traction motor. Similar motors, much more powerful than older types, have also been designed for multiple-unit cars, with the result that one two-motor power truck now provides performance characteristics to a two-car unit which are identical with those of the older equipments, in which one two-motor power truck is used on each car.

Numerous other major improvements have been introduced as the result of the co-operation of the engineers of the electrical companies and the Pennsylvania officers.

Means have been provided for producing all of the necessary power on one phase, instead of two or three, and under normal operating conditions there will be no phase breaks in the contact system — no places where the locomotive must shut off power while it coasts from power from one source to power from an-

other. This means that satisfactory methods have been developed for holding single-phase generators, which are separated by great distances, in step or synchronism with each other.

The electric power from the generators is stepped-up to 132 000 volts by transformers and is transmitted along the railroad right-of-way at this voltage to substations placed from 7 to 10 miles apart, where it is stepped down to 11 000 volts for the contact system. Four parallel transmission lines insure continuity of power supply, and the development of high-speed circuit breakers and relay control has made it possible practically to eliminate all expensive 132 000-volt oil switches. In case of a fault on the trolley system, the relays will select, and the high-speed breakers will disconnect, the particular part of the circuit that is in trouble from the rest of the system in one cycle (a twenty-fifth of a second) and before burning or other trouble caused by the short circuit can cause appreciable damage. The locomotives and multiple-unit cars also depend upon the same breakers for protection.

A simple form of catenary structure has been evolved which is adaptable to various conditions of track and degrees of curvature. A new type of insulator was produced to meet the clearance requirements of the Hudson and East river tunnels, and the tunnel conditions also resulted in the development of concentric cables for the transmission of 11 000-volt, single-phase power.

A bold method for effecting inductive co-ordination between power and communication circuits has been put into practice, in which a parallel to the ground or return circuit of the offending line is actually run in the same ducts with the communication circuits.

High-voltage lightning arrestors have been practically eliminated and a method of lightning protection has been developed which serves to dissipate lightning discharges harmlessly. These and many other engineering achievements have come out of the Pennsylvania electrification.

Type of service rendered.

In the a. c. electrified territory, because of the total density of traffic requiring its fairly definite arrangement, as well as because of the nature of the freight handled, a large portion of which consists of articles or merchandise upon which the delivery time is guaranteed, the freight traffic is almost entirely moved by timed or scheduled trains. There are very few extra freight trains. The number and the time of the scheduled freight trains is arranged from season to season, spring and summer, fall and winter, in such a way as will best serve the traffic it is anticipated will be offered during that season. The different classes of traffic offered are studied and the freight schedules are arranged, so far as possible, to meet the varying requirements of these different freight classifications.

It is apparent that in the electric operation of this arranged traffic, in which the slack times of passenger traffic are filled by freight traffic, the load factors will be better and more nearly uniform, than could be expected with a more haphazard movement.

Facilities required.

When the electrification to Washington is completed it will require approximately 816 000 000 kw.-hr. per year (1 094 000 000 H. P-hr. per year) to operate the total Pennsylvania a. c. traction territory. This represents an average load of 125 000 H. P., the peaks, of course being considerably in excess of this value. It will include 1 519 miles of track, 41 step-down substations ranging in capacity from 9 000 KVA. to 27 000 KVA., and seven supply stations ultimately ranging in size up to 320 000 KVA.,

to supply electric current to the transmission circuits. The total substation capacity of the New York-Washington section will be 1 196 500 KVA.

The requirements also include from 111 to 118 new electric passenger locomotives, 71 to 88 new electric freight locomotives, 14 to 65 new switcher locomotives and 86 to 114 new multiple-unit passenger cars. Thirty-six existing locomotives will be altered for use in this service.

By the first of April there will be 72 passenger locomotives, hauling trains in the territory between New York and Philadelphia, and to Wilmington and Paoli. There are now 345 multiple-unit cars in use and 40 newly-equipped cars about ready for service.

History and development.

In 1910, the Pennsylvania Railroad electrified its line from Sunnyside Yard, Long Island, through the New York Terminal at Thirty-third street in New York City, to Manhattan Transfer, near Newark, N. J. Trains from the Pennsylvania station connect at Manhattan Transfer with Hudson & Manhattan Railroad trains from downtown New York. The terminal electrification required the building of two single-track tunnels under the Hudson river and also made connections through the four East river single-track tunnels with the Sunnyside yards on Long Island. The electrification was necessitated by the terminal and tunnel requirements. Locomotives receiving 675-volt power from a third rail were used to haul trains to Manhattan Transfer, where the electric locomotives were uncoupled and steam locomotives attached to the train. The change from low-voltage, direct current to high-voltage, alternating current was anticipated at the time the tunnels were built and clearances were provided for that purpose.

Suburban transportation by means of multiple-unit cars was initiated between Philadelphia and Paoli in 1915, to provide for increasing suburban traffic and the needs of a congested terminal. This was extended to Chestnut Hill in 1918, to White Marsh in 1924, to West Chester and Wilmington in 1928, and to Trenton and Norristown in 1930, which includes all the suburban services in the Philadelphia area.

The present electrification program, including both passenger and freight service, between New York and Washington, D. C., and westward was authorized in 1928. It will connect the previously existing electrified sections and will provide improved and smokeless passenger transportation between these metropolitan districts. It is expected that the costs of operation and maintenance for both passenger and freight service will be reduced more than enough to justify the installation cost. The equipment used has the capacity to haul heavier trains, to make possible faster schedules and greatly to increase track capacity, although no change in schedules has as yet been made.

Electric locomotives now haul trains through Manhattan Transfer without changing locomotives. At present trains are still brought in from West Philadelphia over the Schuylkill river into the old Broad Street Terminal and out again through West Philadelphia. When the changes now being made in station facilities are completed, through trains will pass through West Philadelphia and a shuttle service will carry passengers between the new passenger station in West Philadelphia and the new underground Broad Street Terminal. Two tracks through the new West Philadelphia passenger station have been put in service on 12 March, and use of the old West Philadelphia station is discontinued.

II. — Locomotives develop 1 250 H. P. per axle.

Locomotive requirements of the Pennsylvania electrification are supplied by four types of motive power as follows : The class P5 locomotive for heavy duty passenger service, having a 2-C-2 or 4-6-4 wheel arrangement; the class O1 locomotive for light duty passenger service with a 2-B-2 or 4-4-4 wheel arrangement; the class L6 locomotive for freight service having a 1-D-1 or 2-8-2 wheel arrangement, and the class B-1 switching locomotive with an O-C-O or O-6-O wheel arrangement.

The axles of the P5 and O1 locomotives are driven by twin motors, through quills. Each motor is rated at 625 H. P. continuous at the driver rim, thus providing 1 250 H. P. per axle. The performance characteristic of the two types of passenger locomotives are the same so that they may be operated separately or in any desired combination; thus with an O1 locomotive 2 500 H. P. is available with two pairs of drivers; with the P5 locomotive, 3 750 H. P. is available with three pairs of drivers; with two O1 locomotives, 5 000 H. P. is available with four pairs of drivers; with an O1 and a P5 locomotive the five drivers provide 6 250 H. P., and with two P5 locomotives, 7 500 H. P. is available.

The axles of the L6 freight locomotive are each driven by one motor which is electrically similar to one-half of the twin motors used for passenger locomotives. A nose suspension of the motors and flexible gear are used in place of the quill drive.

The class B1 switcher was developed some years ago, has been built in quantities for Pennsylvania service and is giving satisfactory performance in operation on alternating current on the Long Island and the Pennsylvania and with modified control when operating on direct current on the Pennsylvania. Similar locomotives with slight modifications will be used on alternating current for extensions to switching service.

Influence of motor design.

The passenger and freight locomotives now in service and under construction were made possible by new types of motor, the design of which was worked out jointly by the electrical manufacturing companies to meet the demands of the Pennsylvania Railroad.

Locomotives of the L5 type developed previously for Pennsylvania service were designed for use either with passenger or freight trains with a modification of gear ratios. They were also adaptable for use on either alternating or, with modified control, on direct current. Jack shafts and side rods were employed as a means of transferring the motor horsepower to the driving wheels. The

Fig. 1. — Class P5*a* heavy-duty passenger locomotive.

available motors did not permit placing between the driving wheels sufficient a. c. motor capacity to handle the tractive forces which the weights on drivers permitted. The new motors now provide between driving wheels sufficient motor

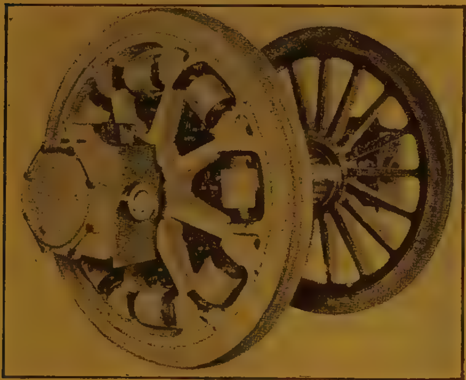


Fig. 2. — A pair of driving wheels with quill and bearings.

capacity to furnish tractive effort to utilize the weight per pair of drivers permitted by the heavy track construction on the Pennsylvania main lines. Jack

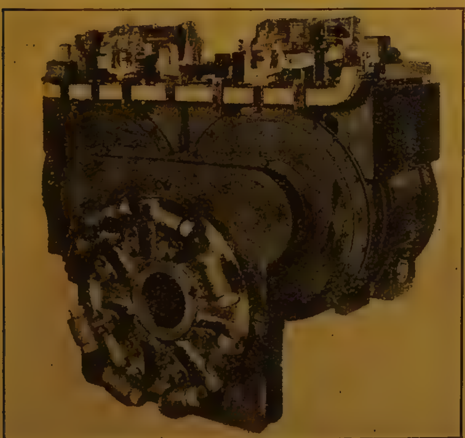


Fig. 3. — Twin motor and quill.

shafts and side rods are thus no longer necessary.

With the motor limitations removed, it was decided after study and review of steam locomotive practice to design an electric passenger locomotive with a weight per pair of drivers of about 75 000 lb. and a total weight of locomotive of about 375 000 lb. These locomotives were designed to duplicate or better the performance of steam locomotives which were handling trains satisfactorily.

To permit increased operating speeds, if found desirable in the future, it was decided that a maximum operating speed of 90 miles should be selected for the passenger motive power. The L6 freight locomotive is geared for 54 miles an hour.

Mechanical construction.

The two passenger locomotives and the freight locomotives are so designed that the maximum number of parts are interchangeable and the general designs are similar. The following description of the construction of the P5 heavy-duty passenger locomotive therefore applies generally to all three types of locomotives.

The P5 locomotive with its 2-C-2 wheel arrangement has a rigid frame between couplers. The cab is mounted directly on the main frame. There is a four-wheel truck at each end and three pairs of driving wheels in the rigid wheel base. A standard A. R. A. swivel shank coupler, mounted in a standard draft gear, is placed at each end of the locomotive, and the entire coupler and draft gear assembly is so designed that removal and replacement is made from the front of the bumpers. The draft gears are held in place by square pins dropped into position from the top of the frame casting. Water and fuel tanks and main air reservoirs are embodied in, and cast with, the main frame. The engine truck

frames, as well as the main frame, are of the integral cast steel type.

The weight of the locomotive is distributed to the wheels by an equalizing system consisting of main springs and equalizers providing a stable system in lateral as well as longitudinal planes. The brake system consists of practically three sets of brakes, each engine truck having its own set and the drivers the third. Clasp brakes are used on the drivers.

The wheel centers are of cast steel, having eight spokes provided with pads for receiving the torque of the motors as transmitted through the gears and quills to the driving wheels. The tires, which are four inches thick, are held on by shrinkage and retaining rings. The outside drivers are flanged and the middle driver is plain. There are three twin armature traction motors on the locomotive, supported rigidly on the crossties of the main frame.

The traction motors transmit power to the drivers through the quill type cup drive, the driving member being on one end of the quill only. In the L6 freight locomotive, single motors are mounted in a frame suitable for axle mounting, and drive the wheels through conventional gear arrangements. Anti-friction roller bearings are used on all journals and also for motor armature bearings.

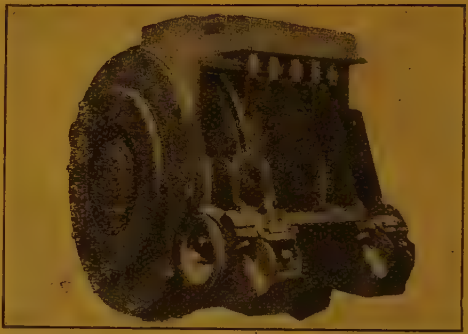


Fig. 4. — Freight locomotive motor.

The quill consists of a hollow cylindrical forging 15 inches in diameter at the quill bearings, with the gear mounted on one end. The driving axle is inside the quill; there is 1 3/4 inches radial clearance between the axle and the inside of the quill to permit freedom of movement between the axle and motor frame while maintaining accurate mesh of the gears and pinions. The quills are secured to the main motors by bearing caps on the main motor frames which, in turn, are attached to the main frame by means of a three-point support. All the movement between the driving wheels and the quill is taken up by sliding contact between the quill spring caps and the driver spokes. The quill

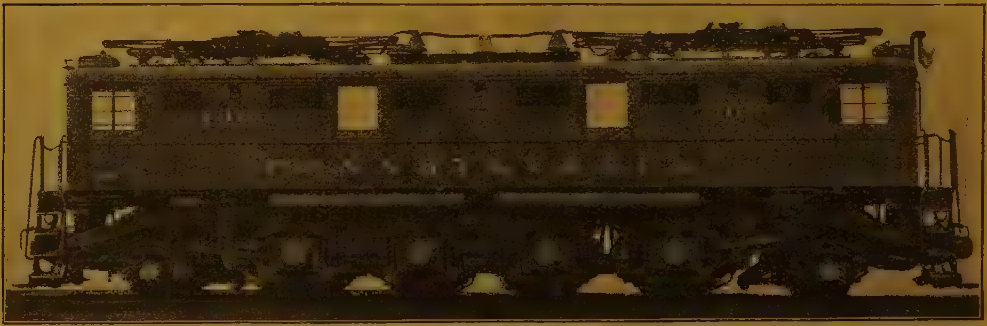


Fig. 5. — Class L6 experimental freight locomotive.

arms, with their spring sockets are attached to the gear center and make contact between the driver spokes. Each armature has a pinion shrunk on one end of the shaft which engages the gear on the quill, and the power is thus transmitted from the motor to the drivers.

The gearing is held is mesh to proper centers by the quill bearings. The upper half of the bearing fits into the main motor frame, and has a brass with a flanged end; it is held in place by the lower brass which is keyed into the cap. The bearing is oil-lubricated. The cap is held in place by four 1 1/2-inch bolts which are secured with nuts and lock washers. The gearing is enclosed in a gear case and is lubricated with grease, suitable openings being provided for refilling.

Cab and apparatus deck.

The cabs are built up of sheet plates and structural shapes. A separate deck for mounting the electrical equipment is so designed that it can be handled as a unit and placed in position on the main frame by a crane. Aisles on each side of the deck facilitate inspection and maintenance. The apparatus deck or unit carries the main control groups, air compressor, miscellaneous items, main wiring and most of the control wiring. The foundation for this unit is a structural framework upon which the electrical equipment is assembled and wired up; the completed unit is then ready for mounting on the chassis.

The cab unit forms a weatherproof housing for the locomotive crew and apparatus. It is sufficiently wider than the apparatus deck to permit an aisle on either side and enough longer to furnish space for the heating boiler at one end, the main transformer at the other, and an operating compartment at either end. The cab structure, in addition to forming a housing, contains the master controllers, an engineers's brake valve, the lighting and its wiring, some of the control wiring, the bells, whistles, headlights, sanders and pantographs, as well as the louvre structure for admitting ventilating air to the motor and transformer blowers. It is assembled as a unit, wired and equipped with apparatus and mounted as a housing on the chassis unit after the deck unit has been installed.

Electrical equipment.

The pantograph or current collectors are mounted on the roof, one near each end. In operation, current is collected from the trolley wire by one of two pantographs and is thence conducted through the high voltage or primary winding of the main transformer to the rail or

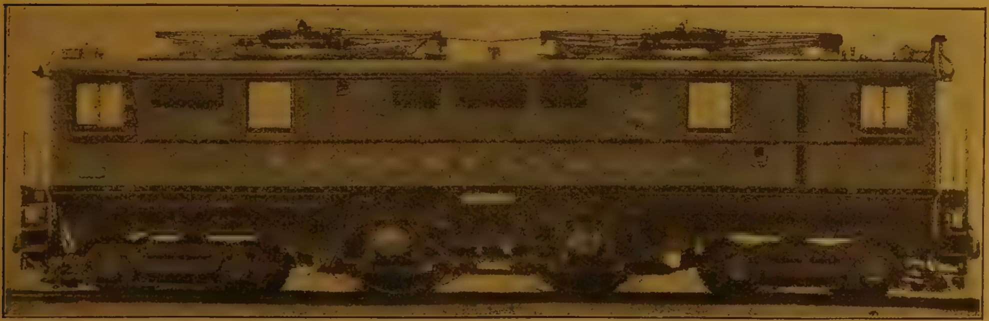


Fig. 6 — Class O-1 experimental locomotive for light duty passenger service.

ground. The two pantographs are connected by a high-voltage bus and, in case of damage to either pantograph, the bus can be divided at the center so that the damaged pantograph can be disconnected and the transformer supplied by the remaining one.

Current is taken from the low-voltage or secondary winding of the main transformer to the traction motors. There are a number of taps on the secondary of the transformer and the voltage to the motors can be controlled by changing the taps to which the motor leads are connected. This is accomplished by air-operated switches controlled electrically from the operating cab. When the locomotive is moving slowly the voltage applied to the motors is low. The counter-electromotive force generated by the motors is also low and the amount of current is relatively high. As the locomotive speed increases the amount of current flowing through the motor winding decreases and the voltage is again increased by the operator to provide the necessary power.

The secondary voltages from the transformers used for motor operation provide voltages varying from 224 to 960. The motors are connected in two groups of three in series, the 1, 2 and 3 motors being in one groupe and the 4, 5 and 6 in the other.

Auxiliary and control equipment.

Only low-voltage battery current is used in the controllers in the engineman's cab and all high-voltage equipment and circuits in the locomotive are enclosed. The equipment compartment contains the high-voltage apparatus which is protected on each aisle side by screens and covers which are kept in place whenever the pantographs are up. Relay and control cabinets are built into the equipment compartment with hinged doors.

Motor-driven blowers for cooling the motors and the transformers are operated from the main transformer on a 384-volt tap. Single-phase motors for this purpose are equipped with a starting winding which is cut out by a relay that functions when air pressure on the blower discharge has risen to a pre-determined value.

The compressor motor, the cab heaters and the blower motor for the oil-fired train-heating boiler are operated from a 224-volt motor tap. The operation of the compressor motor is controlled by the air pressure in the main reservoir; the electrical cab heaters are manually operated, and the air pressure to the boiler burner is controlled by the steam pressure through a damper in the air duct. Air pressure at 70 lb. per square inch for the operation of electro-pneumatic switches is supplied from an auxiliary reservoir which is fed from the main reservoir through a reducing valve.

Direct current power at 32-volts for the operation of control circuits and emergency lighting is supplied by a generator operated by the same motor as the transformer blower and operating in conjunction with a storage battery. When the pantograph is up the lights are supplied by a small transformer, the primary of which is connected to a 144-volt tap on the main transformer. When the pantographs are down, a relay disconnects the lighting circuits from the lighting transformer and connects them to the storage battery. The relay operation is reversed when the locomotive is again energized.

Protective devices.

Faults or grounds in the secondary wiring to the unit switches and in the transformer windings are detected by a relay which selects the defective circuit and opens the controlling switches, or if this does not clear the trouble, or if the fault is in the transformer itself, closes a switch which grounds the pantograph,

causing the adjacent substation breakers to open. After the line is de-energized, the relay lowers the pantograph.

Overload of a motor circuit causes that circuit to be opened; this is indicated to the engineman by the lighting of a signal lamp and by the operation of an alarm buzzer in the cab.

Differential voltage relays check the relative values of voltages across the motors on different wheels, and should the speed of one wheel rise as compared with either of the others due to wheel slippage, the relays will serve to disconnect the motors and prevent overspeeding. The engineman is also apprised of this action in advance by a lamp and buzzer, so that he can normally anticipate the operation of the slip relay by shutting part way off until the wheels cease slipping.

Interchangeable parts.

To facilitate and simplify maintenance, special attention has been given to interchangeability of parts. Any unit or part, armature, motor, brush holder, transformer or control unit on any P5 locomotive will fit into and function properly in any other P5 locomotive assembly, regardless of the manufacture of other parts in that assembly. Close coordination between the manufacturers and the railroad in the development of designs, in checking and approval of drawings, and in other details, was necessary to attain this result.

Each complete locomotive assembly consists of three units : A chassis unit, a deck unit and a cab unit. Each of these three units may be assembled independently of the others and the completed units may then be assembled into a complete locomotive. Parts, such as a pair of drivers, with the drive and motors, a truck, a transformer, etc., may be removed and replaced with a minimum of disturbance to the rest of the locomotive.

Electrical parts on the passenger and the freight locomotives are interchangeable to a remarkable extent. The unit switches, reversers, air compressors and motors, pantographs, motor-driven blowers for motor ventilation and relay systems are identical. The preventive coils and transformers are identical on the O1 and the L6 locomotives, but on the P5 locomotive they are larger because of the greater capacity required.

Although the assembled motors on the O1 and P5 locomotives are of the twin-

Fig. 7. — Class B-1 switching locomotive.

armature, frame-supported type and those on the L6 locomotive are of the conventional single-armature, axle-supported type, the individual parts of the motors, including armatures and stators, are identical except for the frame, end housings and pinion end bearings. The stators may be pressed into or out of either type of frame.

The mechanical parts of the O1 and P5 locomotives are interchangeable to a large extent; the driving wheel assemblies, including the bearings, are the same, truck assemblies are the same, and many parts of the spring and equalizing rigging as well as many parts of the brake rigging are identical. In addition,

many of the parts used to make up the apparatus deck and cab structure are the same.

Every effort was made to insure that each piece of apparatus is readily accessible for inspection and readily removable for repair, so that a locomotive may have a defective piece of apparatus replaced and be returned to service in the minimum amount of time. For this purpose hatches are provided in the roof of all three classes of locomotives. These are readily removable and are so arranged that any piece of apparatus inside the cab may be taken out through one of the hatches for repair or replacement.

Principai weights and dimensions on P5 locomotives.

Diameter of driving wheels . .	72 inches.
Number of driving axles . . .	3
Diameter of truck wheels . . .	36 inches.
Number of truck axles	4
Length of wheelbase (total) . .	49 ft. 10 in.
Length of wheelbase (rigid) . .	20 feet.
Width of locomotive (over-all) .	10 ft. 6 in.
Length of locomotive (over-all).	62 ft. 8 in.
Height to top of pantograph (locked down)	15 feet.
Weight on drivers.	225 000 lb.
Weight per driving axle . . .	75 000 lb.
Total weight.	375 000 lb.
Horsepower, continuous	3 750

A complete driving wheel assembly, including the motors, may be dropped from the frame in the repair shop and replaced in a relatively short time, thus making all electrical parts of the locomotive readily accessible and renewable either from above or below. In addition to this, each piece of apparatus inside the cab may be inspected from the interior of the cab, and the commutators and brushholders of the main motors may be inspected from the inspection pit.

Train heating boilers.

The oil-fired train-heating boilers are located on the number one end of the locomotive. They are of the vertical tubular type and have an evaporating capacity of 4 500 lb. of water per hour at 200 lb. pressure. Water level and steam pressure are maintained automatically, the high-low flame method of pressure control being used. Adequate safeguards are provided to cut off the oil supply in case of low water or other emergencies. Air for combustion is furnished under pressure by a separate motor-driven fan. Control is entirely automatic after the boiler has been fired up.

[656. 254 .73]

Flashing-light crossing signals on the Chicago and Alton•

(*Railway Signaling.*)

In Pekin, Ill., the Alton has recently installed automaticaaly controlled flashing-light signals for the protection of four street crossings at which watchmen were formerly employed during certain hours of the day. The annual saving in operating expense is $2 020, which represents 38 % on $5 200, the total cost of the new signals.

Royal avenue crosses the tracks 600 feet south of the Pekin passenger station, with Fourteenth street intersecting Royal avenue just west of the tracks so that an extra set of flashers is required on the east side of the track. Oakbridge avenue crosses 150 feet farther south, a continuation of Fourteenth street connecting with Oakridge avenue, so that an extra set of flashers is required at this point, as shown on the diagram. Royal avenue and Ookridge avenue carry ordinary street traffic between the business and residential sections of the city throughout the year; additional traf-

Fig. 1. — Reflector-type « Stop on Red Signal » signs are to be added later.

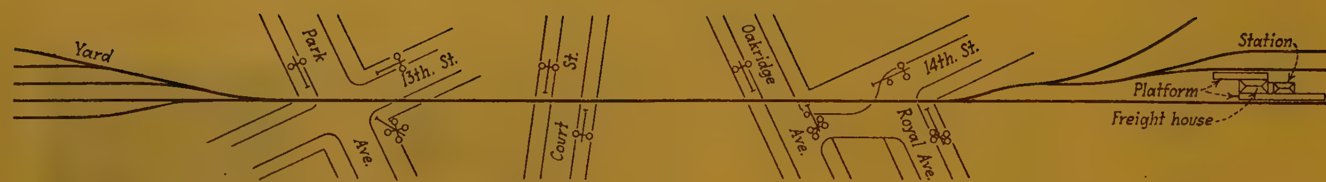


Fig. 2. — Track and signal plan showing territory included in new signal installation.

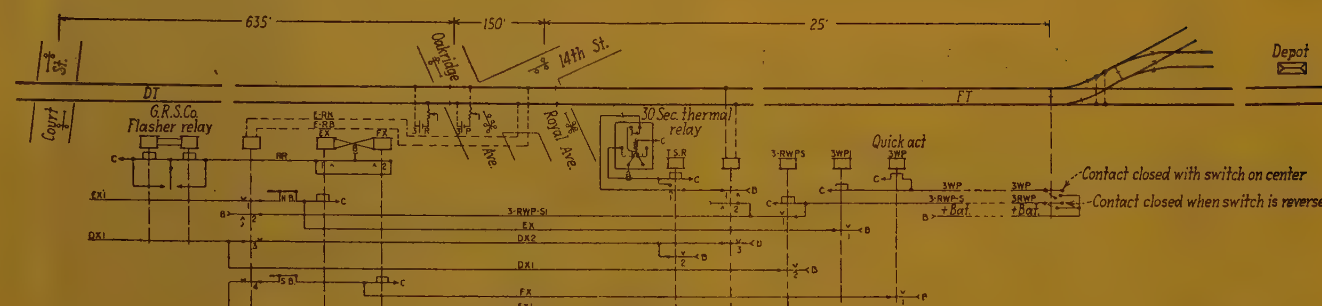


Fig. 3. — Section of circuit diagram showing special control features.

fic, comprising both vehicles and pedestrians moving to and from the park, just east of the tracks, prevails during the summer months. Court street, which carries city traffic as well as through highway traffic, crosses the track 650 feet south of Oakbridge avenue. About 475 feet further south, two streets — Park avenue and Thirteenth street — intersect on the tracks, thus forming a long crossing and necessitating the use of three separate signals, one of which has two sets of flashers.

Under the previous arrangement, all four crossings were protected part-time by flagmen. A man was on duty at Court street from 7 a. m. to 11 p. m., thus requiring two men. One man was on duty from 7 a. m. to 5 p. m. at Park avenue. In the summer months a man was on duty at Oakbridge avenue from 9 a. m. to 6 p. m. and during the remainder of the year this man was shifted to Park avenue. Although this was the most practical arrangement possible, the protection was not satisfactory on account of the part-time protection and the uncertainty on the part of drivers of vehicles that a crossing was being protected. After several conferences with the local city authorities, it was decided that full-time protection with flashing-light signals controlled automatically would be more satisfactory, and the railroad was authorized to make the change.

Control arrangement.

As the train speed through this territory is limited to 25 m. p. h., control sections of from 840 to 1 800 feet were adequate to afford at least 30 sec. operation of the signals before a train arrived at the crossing involved. Unusual conditions were encountered at two points on this installation which required special control circuits. The main line switch, 25 feet north of Royal avenue crossing, leads to the freight house. When switching this house track, a northbound movement would be made from the yard south of Park avenue through the control territory and then into the house track, the signals at Oakridge and Royal being cut out as the rear of the train passes, due to the interlocking feature in the interlocking relays. Frequently the switch engine would not get far enough into the house track to clear the fouling, and would then make a reverse movement over one or both of the streets. In order to make the signals operate for the reverse movement, a special circuit arrangement was used as shown on the typical circuit diagram.

A similar problem was encountered south of Park avenue, for the switch engine pushes cars into the yard, using one of the switches 100 or 195 feet south of Park avenue and then sometimes returns to the main line without clearing the fouling. Therefore, the special circuit was used at this location also.

The accompanying diagram shows the circuit for this special control. When a train enters from the south it shunts track circuit *DT*, thus releasing relay *ET* and the *EX* side of the interlocking relay, which starts the operation of the signals. When the front of the train passes the crossing track circuit, *FT* is shunted, thus releasing relay *FTR* and the *FX* side of the interlocking relay, which then drops on the interlocking pawl. When the rear of the train passes the crossing, *DTR*, *ETR* and *EX* picq up and the signals cease to operate, and would not again operate for a reverse move if the engine did not move beyond the fouling on the siding unless a special circuit was used.

When the switch is reversed, a contact in the switch circuit controller is closed when the switch passes the center point, thus completing a circuit which picks up relay *3WP* and *3WP1* momentarily, which in turn pick up both sides of the interlocking relay *EX* and *FX*, and when the switch is fully reversed, these two relays are released, but *3WP* quick acting relay drops quicker than *3WP1* and for this reason the *FX* side of the

interlocking relay is dropped before the *EX* side is dropped. Therefore, the system is set up for the signals to operate with a train working on track circuit *FT* or for leaving and entering this track circuit.

Special control fort Court street.

Ordinarily the control of the signal at Court street extends through the three track circuits from Court street to the station, *DT*, *ET* and *FT*. However, if a train entering from the north end, stops at the station in track circuit *FT*, it is desirable to stop the operation of the signal at Court street. This is accomplished by means of a thermal relay which is so arranged that if a train consumes more than 30 seconds from the time it enters track circuit *FT* until it enters track circuit *ET*, then the signal at Court street is cut out, the approach

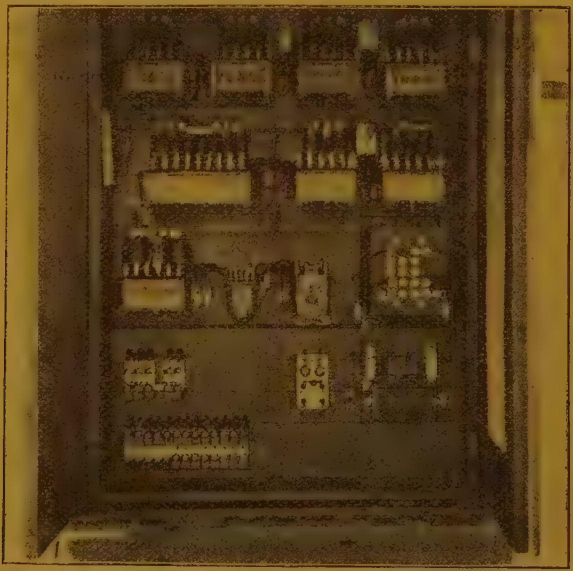


Fig. 4. — The relays and other instruments are mounted in wooden cases.

control being reduced to track circuit *DT* and *ET*.

Likewise, in order to prevent the operation of the signals at Court street when a train is switching in and out of the house track, a circuit is provided so that, when the switch is fully reversed, a contact is closed that picks up relay *3RWPS* which has a contact that in effect eliminates track circuits *FT* and *ET* from the approach control of the signals at Court street. Once this relay *3RWPS* is picked up, it will stay up as long as either track circuit *FT* and *ET* or both are occupied, regardless of the position of switch *S3*, or the number of times it is thrown from normal to reverse.

Power supply.

Each of the track circuits is operated by three cells of primary battery, the Edison 500-a.-h. type being used with a Raco adjustable resistance unit in series.

The lamps in the flasher-light signals are 8 volt, 18 watt. The four signals at

Royal avenue and Oakridge avenue, involving a total of 12 lamp units, and two pilot lights are fed from one set of four 160-a.-h. storage cells. A similar set is used at Court street and at Park avenue. These batteries are the Exide lead type and are charged by Union RX11 dry-plate rectifiers, using W20 transformers.

The relays, rectifiers and battery are housed in special wood cases with sheet-metal coverings set on concrete foundations. The outer door is hinged at the top and jointed at the middle so as to form a shelter for the maintainer during stormy weather. The two inner doors are hinged at the side and form a support for the outer door. The instruments are supported on a partition, the wires being brought in from the rear and extended through holes to the terminals on the instruments. Wires coming in from the outside are brought up trough a hole in the foundation, and terminate on porcelain-based terminals in the bottom row in the case. These cases are made up in three different standard sizes to meet different requirements. The wood is clear pine and has two coats of paint. The galvanized-iron sheet-metal covering is painted with two coats of black paint. The wires from the cases to the signals and to the track are in Okonite parkway cable made up with a lead covering and two wrappers of steel tape. On account of the long runs from the battery to certain signals, No. 8 five-conductor cable is used. No. 8 single-conductor is used for the track connections.

The flasher-light signals, relays, etc., on the installation were furnished by the General Railway Signal Company. The engineering and construction were handled by the signal department forces of the Alton.

[656. 222.5 (.492)]

Summer time.

Motives which led Holland to adopt a different date,

by H. E. VERSCHOOR,
of the Netherlands Railways.

In Europe summer time is in force in Great Britain, France, Belgium and Holland among other countries. The final date of this change of hour is the same in all the above mentioned countries, but as regards the date of its beginning there is a regrettable divergency of opinion, and at the present time the situation is such that there are three different dates for beginning summer time, i.e. that of Great Britain, that of France and Belgium (which has adopted the French dates) and that of Holland. In the case of the Continent — where it would be particularly desirable to have summer time beginning simultaneously in all countries because of our timetables — Holland alone differs in this question and it has often been asked what motives could have kept Holland from falling into line with France and Belgium.

In order to clear the ground we must remember that the annual timetable of the railways in Europe generally begins on the 15 May, and that the countries which make use of the summer change of hour have to make the necessary modifications in their tables to fit the international trains. When summer time begins it is necessary in France, Belgium and Holland — in order to get the trains away promptly from the frontier stations — to delay the trains to and from Germany, Switzerland and Italy by an hour.

As far as Holland is concerned, it is a question of a considerable number of trains, express trains and through (D) trains running from east to west and vice-versa, via the frontier stations of Oldenzaal, Emmerich, Cleves and Venlo. These trains run over portions of the line where the traffic is very heavy (via *Hilversum-Amersfoort*, via *Utrecht*, via *Nimegue* and via *Tilburg*), so that the modifications in the time-table also affect many trains not forming part of the international traffic.

First of all in Holland a supplement was inserted in the *Railway Timetable*, giving these numerous modifications; and afterwards a completely new railway timetable was published. Both methods failed in practice, as neither gave the passengers a sufficiently clear idea of the numerous modifications to be made in the old tables. It must be remarked that in Holland 5 % of the population buys a railway timetable (in France this proportion would be sufficient to account for 2 million timetables) and most of these people do not bother to get a complete or up-to-date timetable for the trains of a period of less than two months.

Another way of meeting this difficulty would be to insert in the October timetable the part to be used in the following spring. This method, however, would have the serious objection of making the railway timetable too complicated to understand, as there would be too many trains only run during part of the season.

Yet another solution would have been, until the 26 March 1933 (date summer time begins in France and Belgium), to hold trains coming from Germany (or

part of these trains an hour at the frontier station, and after the 26 March 1933, to hold back the trains to Germany by an hour, but it was also desired to avoid having to do this in Holland. Consequently it was found preferable to begin summer time at the same time as the beginning of the new international time tables, i.e. on the 15 May. It is true that between the 26 March and 15 May under these conditions, it is necessary to run trains to and from Belgium an hour earlier, but in practice only direct trains via Roosendaal to Antwerp, Brussels, Paris and vice-versa are affected, which trains (because of the geographical position of the country and the distribution of the railway system), affect a much smaller part of the Dutch railways than the international trains through Amersfoort, Arnhem, Nimegue and Tilburg.

From the Dutch point of view, it would be possible to achieve a generally agreed system by making the beginning of summer time coincide with the beginning of the annual timetables (1). This measure would make it necessary to have international collaboration between the governments and railways. In this case not only Holland, but also Great Britain, France, and Belgium would avoid the difficulties which — when summer time is introduced — generally are met with each year in countries where summer time is in force in the case of trains going to and coming from countries where summer time has not been adopted. The above shows that definite collaboration — as regards the internal services — has not been wanting in Holland.

(1) This question has already been the subject of a proposition presented by the Belgian Railways to the Prague (1927) and Vienna (1928) Conferences.

[621. 392 (.42) & 625. 246 (.42)]

London and North Eastern Railway welded wagon underframe.

Since the introduction of the steel-framed wagon in this country the generally accepted practice has been to join the various members forming the frame by means of rivets and suitably shaped knees. This procedure has proved satisfactory, and is still in general use. One of the chief advantages of this method is the ease with which the joints may be broken and remade when it is necessary to remove defective members for repairs or renewal.

The accompanying drawing, figure 1, shews the arrangement of the steel underframe which has been standardised for all types of goods wagons in Great Britain. The whole of the main and subsidiary members are of channel section

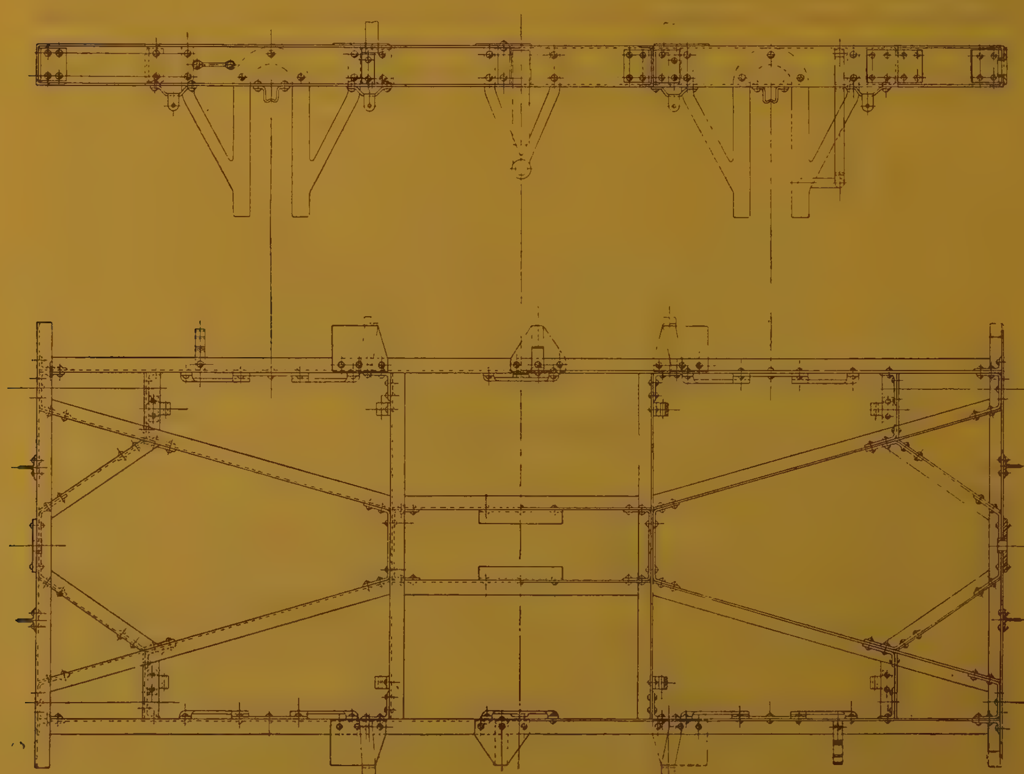


Fig. 1. — Riveted underframe for 12-ton standard wagon.

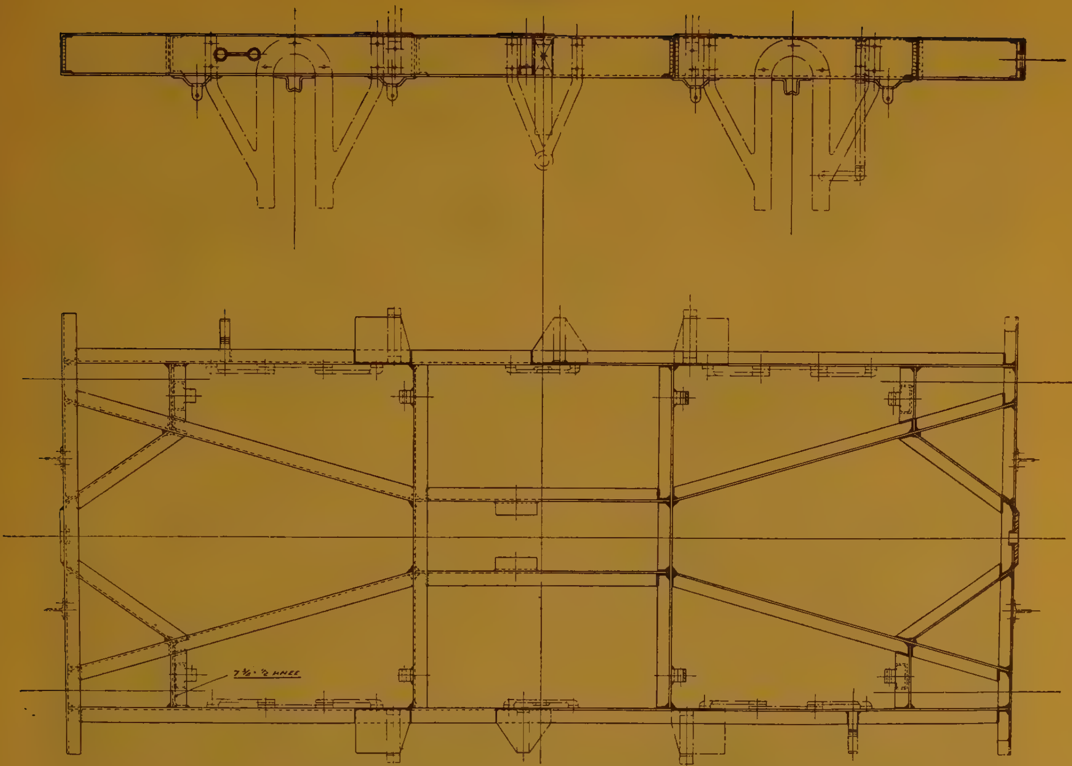


Fig. 2. — Experimental welded underframe for 12-ton standard wagons.

Fig. 3.

steel 9 in. × 3 1/8 in. × 7/16 in. built up in the manner previously described.

The rivets and knees necessary to this method of construction represent so much added weight to the frame, whilst the manufacturing costs are comparatively high on account of the variety of operations required prior to the actual riveting of the frame. This preparatory work involves the jigging and drilling of all frame members and knees, the manufacture of the knees in the smithy, and the final assembly of the various units either by temporary bolts, or by means of a suitable jig if the number of frames to be built warrant the cost of the latter.

With a view to overcoming some of these objections, an experimental 12-ton standard high sided goods wagon, with a steel frame to R. C. H. dimensions, has recently been built at the Dukinfield Works of the London and North Eastern Railway, but in place of the riveted joints electric arc welding has been employed.

Reference to the accompanying drawings and photographs will indicate the general appearance of the frame, and the extent to which the welding has been carried out.

The procedure adopted for the construction of the frame was as follows.

All members were first cut to correct length by high-speed circular saw, and, where necessary, the ends shaped by milling or oxy-acetylene cutting to provide a close abutment on both web and flanges of the adjoining members.

The next operation was the drilling of the sections prior to assembly. Owing to the absence of all jointing knees, the number of holes to be drilled was considerably reduced, the number actually required being 170 as compared with 800 in the standard riveted frame. Of these 170 holes, a large proportion is necessary for the holding down bolts for the floor boards, whilst the remainder are required for securing the body stanchions, the side door check springs, the axleguards and the brake hanger brackets. The holes for the buffing gear in the headstocks and buffer trimmers, and the drawbar holes through the headstocks and cross bars are included.

In the absence of an assembly jig suitable for a welded frame, it was necessary to commence erection by setting out the solebars and headstocks in their correct relative positions on trestles. These members were carefully squared up and the top and bottom flanges secured by « tack welding » at the four corners. After this the drawbar plates were welded to the faces of the headstocks and trunnions fixed in position by bolting through the drawbar holes which had been previously cut out by the oxy-acetylene burner.

The structure was next lifted into position on stands enabling it to be rotated on the trunnions. By this means it was possible to « gravity weld » all joints in the horizontal plane. The remaining members, consisting of cross-bars, diagonals, buffer trimmers and diagonal stays were then arranged in the above order in the frame, and « tack welded », after which all joints were built up with welding wire to the required thicknesses. It should here be mentioned that the joints were not specially prepared in any way to receive the welding. The webs of all sections were welded on both sides with a continuous fillet from 3/4 in. to 1 in. wide, whilst the flanges were lightly welded on the inside only.

In the case of the standard riveted frame the buffer abutments are considerably reinforced by the solebar and diagonal knees. As these are dispensed with on the welded frame it was decided, by way of experiment, to replace them at one end of the frame only by stiffening plates 1/2 in. thick × 7 3/4 in. wide shaped to fit between the flanges of the buffer trimmers and to bend round and joint up to the webs of the

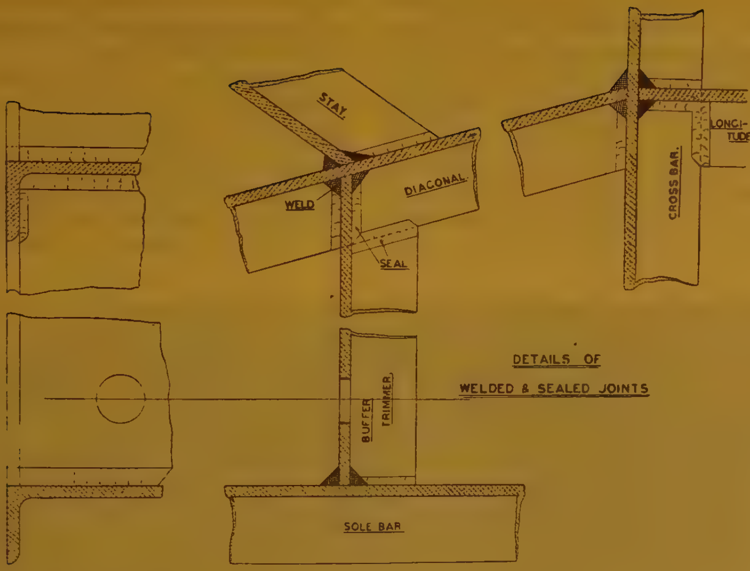


Fig. 4.

solebars and diagonal members. These plates were welded into position by a continuous fillet round their edges. In the test which followed, the plates were found to be superfluous, the welded joints securing the unreinforced buffer trimmer proving sufficiently strong.

The remaining items to be welded to

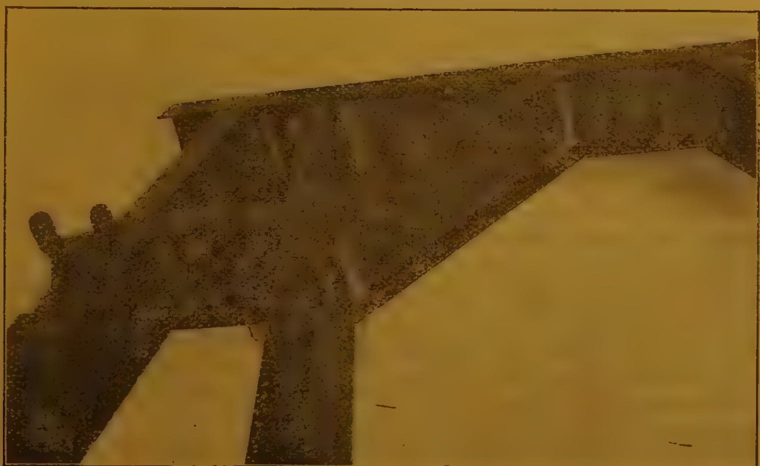


Fig. 5.

the frame were the bearing spring shoes and stops, the brackets for the brake lever guards and brake block hangers, the centre body bracket, the body gusset plates, the drawbar cradle carriers and the horse hooks. Particular care was taken in welding up these details to guard against the necessity for renewal in traffic. Following this the wagon was built up in the usual way, all details requiring ready removal, such as axle-guards, end and body stanchions, etc., being bolted in position.

To determine the efficiency of the welded structure, it was decided to subject the completed wagon to the most severe shunt that it would be likely to encounter when in service.

For this purpose a section of line was selected having a slight curve and

Fig. 6.

falling gradient. A suitable stop was provided at the end of this road by means of seven empty coupled wagons, all of which were braked and spragged.

The experimental wagon, after being loaded with a moveable load of 5-tons was coupled in front of a train of six loaded wagons and fly-shunted into this stop at varying speeds. These were checked by the time required to cover a measured distance from the end of the wagon forming this « stop ».

Two shunts were first made, one at 4 m. p. h. and one at 12 m. p. h. without any effect on the wagon under test. A third shunt was then made at a speed of 17 m. p. h. resulting in damage to a number of wagons in the train. An idea of the intensity of the impact may be obtained from the accompanying photograph, figure 6, which clearly shews the damage sustained by two of the wagons immediately following the one on test.

The seven shunted wagons weighed 77 tons, the accumulated energy at the moment of impart being 1925 foot tons per second.

A careful examination of the welded frame after the tests shewed that no joints were affected whilst the only de-

fect in the frame generally was a cross corner distortion of approximately 1/4 inch.

The resultant saving in weight and labour charges by welding are encouraging. The weight of the bare welded frame was 1 ton 4-cwts, as compared with 1 ton 9-cwts for a similar riveted frame, a saving of 5 cwts, or approximately 17 % on the weight of the riveted frame.

The resultant saving in weight and Dukinfield Works of the London and North Eastern Railway Company in conjunction with Messrs. Murex Welding Processes Ltd., to the requirements of Mr. H. N. Gresley, the Chief Mechanical Engineer.

MISCELLANEOUS INFORMATION.

[625 .143.4 (.42)]

1. — Short fishplates, London & North Eastern Railway.

(The Railway Gazette.)

Two-bolt fishplates were tried experimentally in 1926 by Mr. John Miller, Engineer, North Eastern Area, London and North Eastern Railway, and have been found so satisfactory that they have been adopted for general use in that area. The short plates have the advantage of cheapness, being little more than half the cost of the standard plate. They also tend to reduce the hammer at the joint, as the joint sleepers are placed closer together, giving a more concentrated bearing and a much decreased deflection of the rail ends. The short plate also has a very much greater resistance to fracture than the longer plate; so much so, that breakages have virtually been eliminated.

Another interesting feature in the use of short fishplates is that a considerable percentage of long plates which are continually being taken out of the track on account of fracture

Fig. 1.

can be utilised again instead of going on to the scrap heap. The method in this case is for the fractured long plate to be cut through the centre into two 9-inch lengths, each length having two bolt holes. One half, containing the fracture, is scrapped; the sound half plate is heated and one of the bolt holes is slightly elongated to make the hole centres 5 inches to suit the standard rail drilling. The half plates are then issued for general maintenance purposes or for use in minor lines. Many thousands of cracked and broken plates have been utilised in this way in lieu of new plates at a fraction of the cost of the latter and with a constant decrease in the cost of upkeep.

[625. 17 (.42)]

2. — Permanent way maintenance costs.

(The Railway Gazette.)

Investigation of the published returns of the British group railways since 1923 discloses many interesting facts as regards both earnings and expenditure. So far as expenditure of the various departments is concerned, Abstract A, which covers maintenance of way and works, is an important one, and of especial interest are comparisons of expenditure under this abstract in relation to train mileage on each of the group railways.

While it may be contended that an analysis of expenditure on a train-mileage-unit basis does not produce ideal results, this basis is probably the most useful one available and gives, on the whole, as fair a comparison as it is possible to make. We reproduce a diagram of way and works expenditure on this basis for the four main line railways covering the period since grouping became effective. Examination of this diagram discloses that the expenditure in 1923 varied from 14.69 d. to 17.55 d. per track mile; since then there has been a steady decline in the rate of expenditure on all the railways, while at the same time they are all tending to approach a uniform figure, and in 1932 the variation between the minimum and the maximum is less than 0.6 d. per train mile. Included in the figures is the cost of maintaining electric track equipment. This item, on the Southern Railway which now has about 25 % of its total mileage electrified, would, of course, be much larger than in the case of the other groups.

A second diagram shows the number of train-miles per single track-mile which are run over the lines of the different systems, and from this it will be seen that the intensity of traffic over the whole of the Southern Railway has increased since 1923 by 25 %, whilst that of the other three groups has been slightly reduced in the same period.

Concurrently, the cost per train-mile on the Southern has decreased from 16.6 d. to 11.6 d., a reduction of 30 %. Reductions in cost of living and rates of wages would probably account for about one-third of this. The fact emerges from these figures that notwithstanding the much greater intensity of traffic over the electrified lines which continually increases the difficulties of the permanent way department, the steps which have been taken to meet

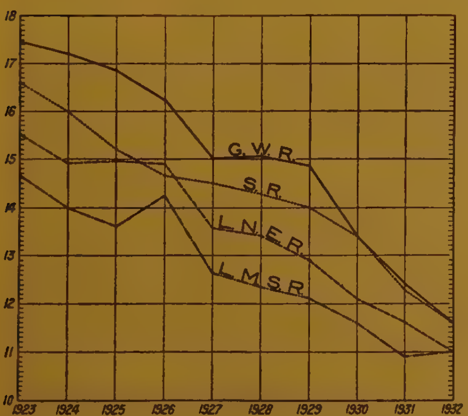


Fig. 1. — Way and works expenditures per train-mile.

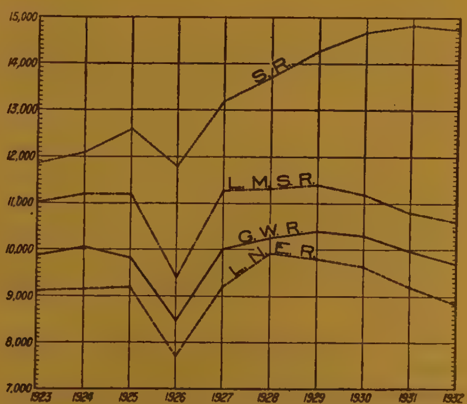


Fig. 2. — Traffic density per track-mile.

the extra wear and tear have resulted in an actual reduction in the total cost of the maintenance of the line, which in 1923 amounted to £3 383 763, and in 1932 to £2 958 845. It should also be borne in mind that 88 1/2 % of the total traffic on the Southern Railway in 1932 was passenger traffic, as against 64 % London Midland & Scottish Railway, 61 1/2 % London & North Eastern Railway, and 64 % Great Western Railway.

With the intensified electric traffic there is certainly considerably more work to do on the track, whilst the periods or time available in which to do it are much reduced. It is, therefore, a considerable achievement to have reduced so substantially the total cost of the maintenance of way and works and at the same time to have catered for a total increase in train mileage of not less than 25 %.

The fact that the train mileage has increased by 25 % over the entire system does not perhaps sound very impressive, but it should be remembered that over the whole of the suburban lines of the Southern Railway on which there was already an intensive steam traffic, the train mileage was increased approximately two and a-half times.

We have previously referred in these columns to the various measures of economy which have been adopted in the work of track maintenance, such as (1) the welding of worn crossings, (2) the use of special rails such as manganese and sorbitic steels, (3) the oiling of curves, (4) the use of spring crossings, (5) and the reorganisation of manpower. The diagrams we now publish seem to confirm the effectiveness of these measures.

[686. 253]

3. — Double-filament lamp with dividing screen gives burn-out indication,

by Charles ADLER, Jr.

Signal Engineer, Maryland & Pennsylvania Railroad, Baltimore, Md.

(*Railway Signaling.*)

The almost universal use of light signals by the railroads of the U. S. A. has brought to the fore the problem of guarding against failure of the incandescent source of illumination. When a failure of this nature occurs in a signal dependent upon a single incandescent lamp for the display of its aspect, two undesirable conditions are created : First, the possibility of a delay to train movements; and second, the potential danger of an engineman's failure to see the signal, in its unlighted condition.

One of the important functions of light signals is the protection of highway traffic at railroad crossings; and it is of paramount importance that the standard aspect of two red lights flashing alternately, be kept uniform at all times. The burning out of a lamp in one of the flashing units will cause this wig-wag form of indication to be changed to that produced by a single flashing lamp. Such an indication may at night be readily confused with the constantly flashing highway beacon lights which have a meaning foreign to that of the highway-crossing signal.

Recognizing the importance of the lamp-outage problem, the Maryland & Pennsylvania has installed in its alternate-flashing-light signal at Cold Spring Lane crossing in Baltimore, double-filament screened lamps recently developed and made available by the Union Switch & Signal Company. This type of lamp is constructed with two filaments placed parallel with each other and slightly spaced

Fig. 1. — Position-light dwarf signal.

Note clear-cut division of light in left unit in which one filament is burned out.

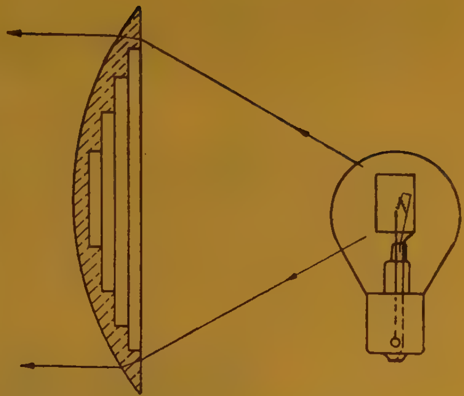


Fig. 2. — A small metal shield is mounted between the two filaments.

by a centrally located metal screen. Normally, both filaments are incandescent and the entire bulb is illuminated. However, upon the failure of either filament, the screen causes the lamp to be divided into contrasting bright and dark halves. This effect is reproduced on the signal lens and thus gives unmistakable notification that the lamp should be replaced. At the same time brilliant illumination is still provided on the bright half of the lens, enabling the signal to be read clearly. To guard against the possibility of the simultaneous failure of both filaments of the lamp, the filaments are constructed of slightly unequally rated life.

While installing the screened lamps at Cold Spring Lane crossing, a sample lamp having one filament disconnected, was placed in one of the signal units, and the telltale failure indication produced on the lens was clear-cut and arrestive. The maintenance men were shown this indication and instructed to inspect the signal at regular intervals, replacing the lamp behind any lens showing the failure aspect. The sample lamp was then removed, and lamps having both filaments operative, were permanently installed. The illumination given by the new lamps was found to be equal in brilliancy to that afforded by those of similar wattage formerly used. Other light signals on the Maryland & Pennsylvania will be equipped with the screened lamps in the near future.

[656. 254. (73)]

4. — Primary battery floating on storage for the operation of crossing signals.

(Railway Signaling.)

The Missouri Pacific has recently installed flashing-light highway crossing signals at Huggs crossing on a single-track line near Crystal City, Mo., to replace Hoeshen-type signals formerly in service at this point. As this crossing is not in automatic block signal territory and is remote from any commercial current supply, it was decided to use primary battery not only for the track circuits but also for the operation of the flashing-light crossing signals.

Three cells of primary are used on each of the two track circuits and the operating battery consists of 13 cells of primary floating across 4 cells of lead storage battery. The constant discharge of the primary battery is adjusted, by means of Raco resistance units, to between 50 and 60 m. a. As explained by the Missouri Pacific, the purpose of using the storage battery in this arrangement is to secure a constant voltage for the operation of the signals, and a second advantage is that the full life primary battery can be utilized without the hazard of a failure or dimming of the lights near the end of the life of the battery. The primary cells are the Edison 500 a.-h. multiple-plate type and the storage cells are the Exide KXHS 7, of 78 a.-h. capacity.

Fig. 1. — A. R. A. standard « Stop on red signal » signs are used.

The flashing - light crossing signal units

are the General Railway Signal Company Type-XB, affording indication in both directions, the front lens being 8 3/8 inches and the back lens 6 1/2 inches. Each lamp unit has a 10-volt. 10-watt bulb. Each signal is equipped with the standard American Railway Association (A. R. A.) « STOP on RED SIGNAL » reflector, button type of sign. A Railroad Supply Company type-D crossing bell is mounted on one of the signals.

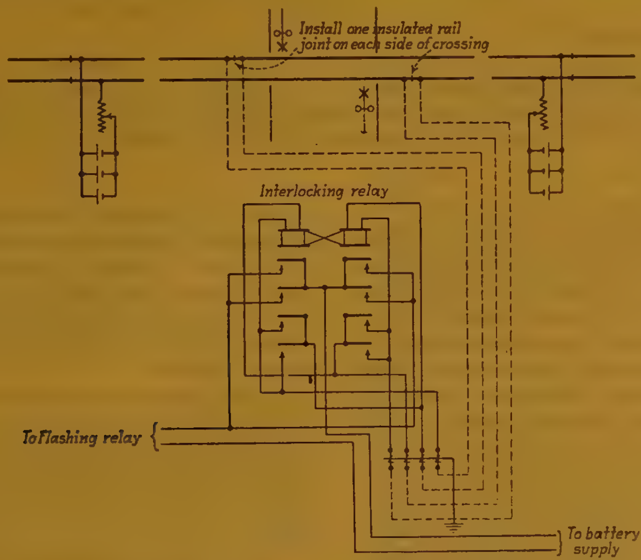


Fig. 2. — The signals operate until rear of train clears ihe crossing.

Fig. 3. — The primary and the storage batteries are housed iu one bov.

The control circuits are arranged so that the signals continue to operate until the rear of the train passes the crossing, regardless of the direction of the movement. This result is effected by locating one insulated rail joint on one side of the crossing and the other on the other side, and by using the circuit explained in an article on page 348 of the September 1928 issue of *Railway Signaling*. From the diagram it will be seen that an approaching train, upon de-energizing one side of the interlocking relay, shunts one of the two insulated rail joints at the crossing, through the back contacts of the de-energized side of the relay. This shunting of the joint extends the track circuit over the crossing and prevents the side of the relay first de-energizing from picking up until the entire train has cleared the crossing. The signal, therefore, continues to operate for a train in either direction until the highway is open for traffic.

NEW BOOKS AND PUBLICATIONS.

[621 .13 (02 (.42)]

Locomotive Engineer's Pocket Book, 1933. — Published by the Locomotive Publishing Co., Ltd., 3, Amen Corner, Paternoster Row, London E. C. 4. — 1 vol. (6 1/2 × 3 1/2 inches), clothbound, of 390 pages, with numerous formulae, diagrams and tables. (Price : 3 sh. 6 d.)

This excellent pocket-guide, the 1933 edition of which has now been issued, is intended for traction engineers and steam locomotive builders. It places at their disposal a mass of data, information, formulae, and numerical tables for use when designing locomotives : calculation of train resistances, study of combustion, vaporisation, the power of the boiler, and the calculation of its dimensions; calculation of the tractive effort; distribution of weight on the axles; counterbalancing; stability on curves; calculation of the frame and spring gear; design of the mechanism, etc., etc. Most of these paragraphs include examples in which the applications have been completely worked out.

A special chapter is devoted to locomotives of special types : turbine, electric, with internal combustion motors, etc. Other chapters give useful information about the driving, maintenance and repairing of locomotives, as well as information about the working of locomotive depots.

In the Appendix are tables showing how to convert English weights and measures into metric equivalents, as well as diagrams and numerical information about the chief English types of locomotive.

This brief enumeration will give some idea of the great value of this little book for traction engineers and offices dealing with the design and construction of locomotives.

A. C.

[385 .15]

Dr. jur. Bernhard WITTE, Vice-President, German State Railways. — **Eisenbahn und Staat.** Ein Vergleich der europaischen und nordamerikanischen Eisenbahnorganisationen in ihren Verhaltnis zum Staat (**Railways and the State.** A comparative study of the organisation of the European and North American Railways and their relations with the State). — One volume (9 7/16 in. × 6 5/16 in.) of 272 pages. 1932, Iena, Publisher : Gustave Fischer.

This work has been published in the *Weltwirtschaftliches Archiv* series — World economic archives — of the Institute of Economic and Maritime Studies of the University of Kiel, under the leadership of Bernhard Harms, Doctor of Political Science, and Professor at the University of Kiel.

The scope of the book is indicated by its title. It consists of a series of well considered monographs on the subject of the organisation of the different European railways, on their relations with their respective States, the modifications made in their byelaws since their formation, and their present situation.

Owing to the extensive detailed sta-

tistical information given by the author it is difficult to give in short an account of the contents of the book.

No better idea of the contents and of the extent of the subjects treated can be given than by the following summary of the table of contents.

Part 1. — Historical development and present position of the organisation of the different railways in their relationship with the State.

I. — Extent of State owned and privately owned railways in Europe and the whole world.

II. — Organisation of railways in countries with State ownership.

III. — Organisation of railways in countries with private ownership.

Part 2. — Detailed study of the organisation of railways as concerns in particular their relations with the State.

I. — The growing autonomy found in countries with State railways.

Under this heading the author examines in turn questions relating to administration, finance and politics.

II. — The decreasing autonomy found in countries where the railways are privately owned.

This chapter includes an examination of the grouping, the control services and similarities in organisation of the railways.

Part 3. — The principles governing equilibrium between the systems of operation by the State or private companies.

The author examines concrete examples of the points of agreement in the two methods of operation.

Finally in a chapter devoted to conclusions, the author indicates the questions still to be solved in the future as regards the relations between the State and the railways.

Although there are nearly three hundred pages in this book it is relatively condensed, considering the magnitude of the subject with which it deals.

The author has succeeded in condensing the interesting particulars and in giving in a well developed synthesis the most characteristic features in the different railway organisations and their relations with the State.

This book is a valuable and interesting mine of information and can be read with profit by specialists in this question.

R. D.

[**621. 13** (.73)]

La locomotive à vapeur aux Etats-Unis (The steam locomotive in the United States). — Text of a lecture given by W. DICKERMAN, President of the American Locomotive Company, to the University of Princeton, 14 April, 1931. A pamphlet (11 13/16 in. × 9 1/16 in.), of 26 pages, with copious illustrations, published by the « Office pour le perfectionnement de la traction autonome sur les chemins de fer » (Office for improving railway traction by self-propelled vehicles), 3, rue Portalis, Paris (VIII^e^).

This pamphlet gives the French text of a very interesting conference given by Mr. Dickerman, President of the American Locomotive Company, on the situation of the railways in the United States during the 1920-1930 period, dealing in particular with the evolution of the steam locomotive during this period and the preponderant role played by it in the development of transport by railway. The conference was given in the form of a commentary on a series of 16 synoptic tables representing successively, for the period concerned :

1) The development of the railway

system in the United States as compared with that of the railways of other important countries; the situation of the stock of steam locomotives, the increase of the total tractive effort, and especially of the average tractive effort at the drawbar;

2) the situation as regards rolling stock;

3) the passenger and goods traffic;

4) the operating results; receipts, expenditure, taxes;

5) the distribution of the goods traffic among the different methods of transport : steam railways, electric railways, road motors, aeroplanes, pipe-lines, water transport;

6) the territorial distribution of the railway system;

7) the distribution of the capital invested in railways;

8) the evolution of the goods services : average tonnage per train, total paying tonnage transported, total coal consumption, total tractive effort of the goods locomotives;

9) the tonne-kilometres per train-hour;

10) the adhesive weight and the starting effort of goods locomotives;

11) the adhesive weight of the locomotives and the loads of goods trains;

12) the same factors in the case of passenger trains;

13) the increase in the distance run by passenger locomotives;

14) the average age of locomotives;

15) the advantages to be obtained by renewing the locomotive stock;

16) the different factors affecting the efficiency of railways operated in an up-to-date way.

The author stresses the considerable progress made during the last ten years as regards the efficiency of the steam locomotive; he insists in particular upon the advantages from all points of view to be obtained by replacing antiquated machines by modern units, and he expresses his faith in the future in which the superiority of railway transport must be looked for in long-distance runs for the locomotives and in the rapidity with which the goods are carried.

A. C.

[621. 13 (09 (.43)]

BENAERTS (P.), Fellow of the University, Doctor of Literature. — **Borsig et les débuts de la fabrication des locomotives en Allemagne** (Borsig and the beginning of locomotive building in Germany). — One volume (9 7/8 in. × 6 3/4 in.) of 76 pages. F. H. Turot, Publisher, 23, avenue de Messine, Paris (VIII^e^).

The foundation of the firm of Borsig, one of the great names which dominate the history of the development of German industry, coincided with the beginning of the construction of railways in Germany. Mr. Benaerts relates how Augustus Borsig, nearly one hundred years ago, set up in Berlin a small shop in which the first steam locomotive of German design was built about 1841. We then follow the development of the firm, at first under the management of its founder, and then under his descendants. In the space of ten years, Augustus Borsig outdistanced all his rivals among foreign locomotive builders, and obtained nearly all the orders of the Prussian Railways. We are then shown the decisive influence of the firm of Borsig in the development of the locomotive industry in Germany.

Apart from the economic interest of the history of any great industrial enterprise, there is a lesson of will-power

and tenacity to be learnt from Mr. Benaert's book which makes the reading of it of particular value.

We also desire to mention the very interesting study by the same author on the creation of the railway system and the general development of communications in Germany, in his work : *Les origines de la grande industrie allemande (The origins of large industry in Germany)* (1).

A. C.

[625 .233 & 625 .234]

Train Lighting and Heating. — Published by The Locomotive Railway Carriage and Wagon Review, 3, Amen Corner, London E. C. 4. — 1 vol. (11 × 9 inches) of 134 pages, with many photographs and diagrams. (Price : 7 sh. 6 d. or 5 Rupees.)

The periodical, *the Locomotive, Railway Carriage and Wagon Review,* has issued as a supplement a very detailed study of the electric lighting of passenger trains, applications of which have been increasingly made use of in recent times. Certain countries have indeed made this method of lighting obligatory, and the effect of this measure on the convenience, comfort and safety of the passengers is indisputable.

The work begins by giving the general principles of electric lighting and a general description of the equipment. It then goes on to deal in detail with the principal systems of lighting in passenger coaches : A. S. E. A., Brown-Boveri, Dalziel, Dick, E. S. B., E. V. R., Ganz, Mather and Platt, Oerlikon, Pintsch, Rotax-Leitner, Safety, Stone's, U. S. L., Vickers, and Wolverton; each paragraph gives the wiring diagram of the system.

In the second chapter some through control lighting systems by means of turbo-generators on the locomotive are dealt with : Pyle National, Schneider, French Nord System, as well as arrangements for continuously controlling the lighting in the case of the above mentioned self-contained systems. A third part deals with the specifications of the different parts, gives a description of the arrangements and driving of the dynamos, particulars relative to accumulator battery sets and their accessories; finally there is a paragraph dealing with the maintenance of the equipment.

The work ends with a description of a certain number of the systems of steam heating for passenger trains, and in particular with the Great Western, Westinghouse, Wild, Still and Gresham and Craven methods. It is obvious, therefore, that this interesting book gives the railway engineer and carriage builder very precise information, particularly complete as regards electric lighting.

A. C.

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(1) *Les origines de la grande industrie allemande.* One volume in-octavo, 687 pages, 11 maps, 3 diagrams. Paris 1933. F. H. Turot, publisher, 23, Avenue de Messine.